

Lanka Education and Research Network

Cryptography Basics and Applications

Cryptography

- Cryptography deals with creating documents that can be shared secretly over public communication channels
- Cryptanalysis = code breaking
- Cryptography is a function of plaintext and a cryptographic key

$$C = f(P, k)$$

Notation:

Plaintext (P)

Ciphertext (C)

Cryptographic Key (k)

Is it only for Messages?

- Digital Signatures
- Anonymous communication (TOR Network)
- Anonymous digital cash (Bitcoin etc)
 - Spending a digital coin without anyone knowing my identity
 - Buy online anonymously?
- Elections and private auctions - Finding the winner without actually knowing individual votes (privacy)

History

Caesar cipher, a mono-alphabetic system in which each character is replaced by the third character in succession

Vigenere cipher, a poly-alphabetic cipher that uses a 26x26 table of characters (14-15th Century)

Kerckhoff's Law (1883)

The system must not be required to be secret, and it must be able to fall into the hands of the enemy without inconvenience.

In other words, the security of the system must rest entirely on the secrecy of the key.

Modern Crypto...

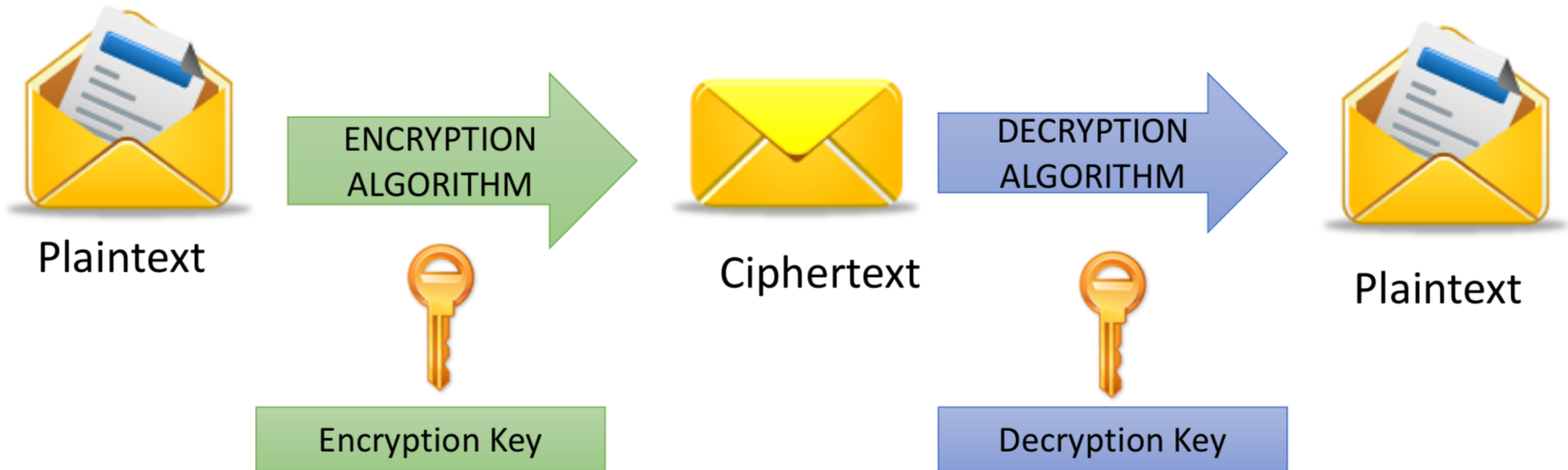
- Specifies the mathematical transformation that is performed on data to encrypt/decrypt
- Crypto algorithm is NOT proprietary
- Analyzed by public community to show that there are no serious weaknesses
- Explicitly designed for encryption

Try:

<https://cryptii.com/>

Encryption

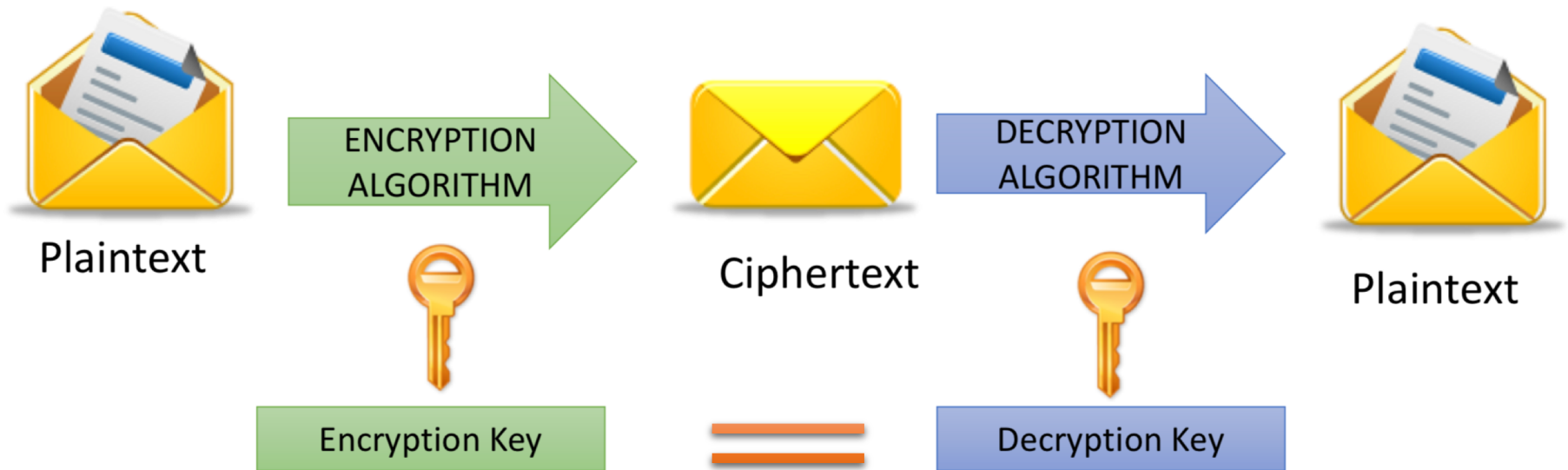
- Process of transforming plaintext to ciphertext using a cryptographic key
- In Application Layer – used in secure email, database sessions, and messaging
- In session layer – using Secure Socket Layer (SSL) or Transport Layer Security (TLS)
- In the Network Layer – using protocols such as IPsec



Symmetric Key Encryption

- Uses a single key to both encrypt and decrypt information
- Also known as a secret-key algorithm, The key must be kept a “secret” to maintain security; This key is also known as a private key, but needs to be shared with all participating in the conversation
- Follows the more traditional form of cryptography with key lengths ranging from 40 to 256 bits.

Eg : DES, 3DES, AES, RC4, RC6, Blowfish

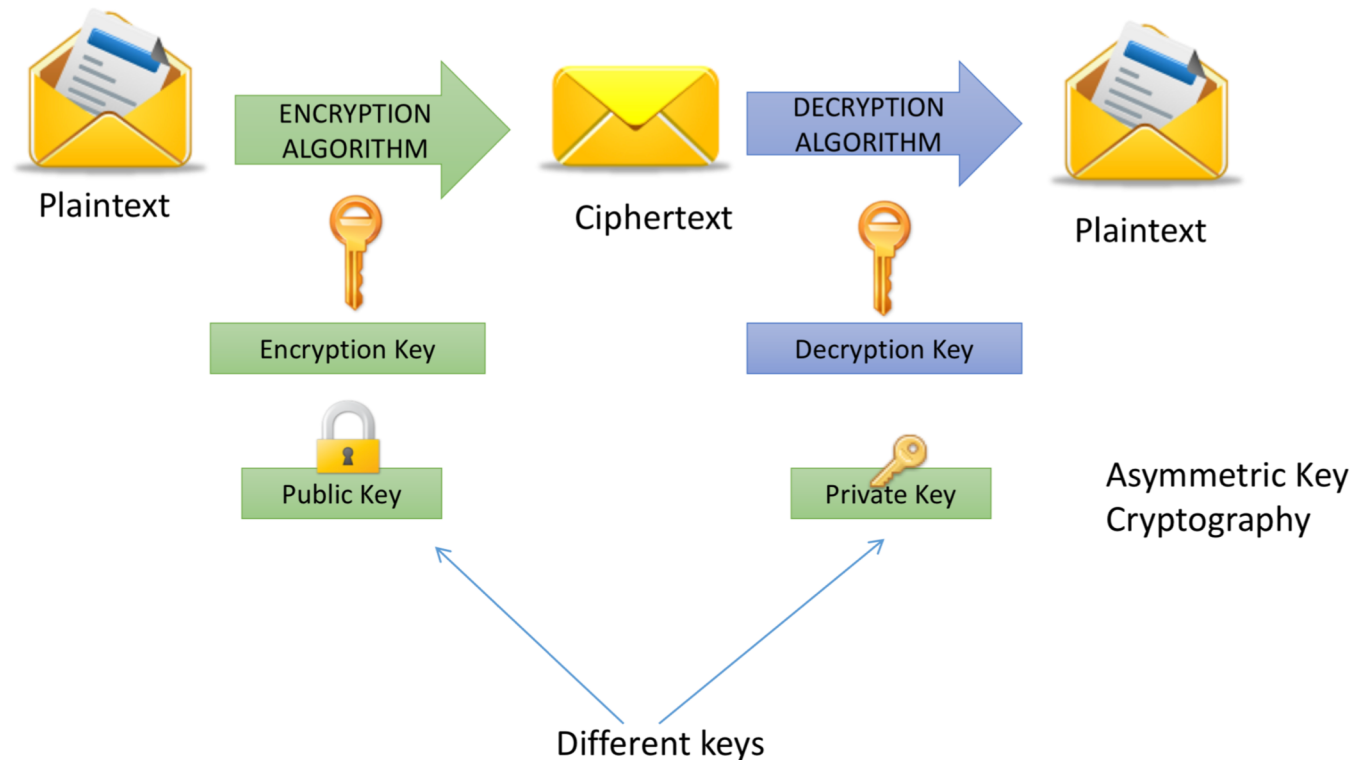


Symmetric Key Encryption

Algorithm	Type	Key Size	Features
DES	Block Cipher	56 bits	Most Common, Not strong enough
TripleDES	Block Cipher	168 bits (112 effective)	Modification of DES, Adequate Security
Blowfish	Block Cipher	Variable (Up to 448 bits)	Excellent Security
AES	Block Cipher	Variable (128, 192, or 256 bits)	Replacement for DES, Excellent Security
RC4	Stream Cipher	Variable (40 or 128 bits)	Fast Stream Cipher, Used in most SSL implementations

Asymmetric Key Encryption

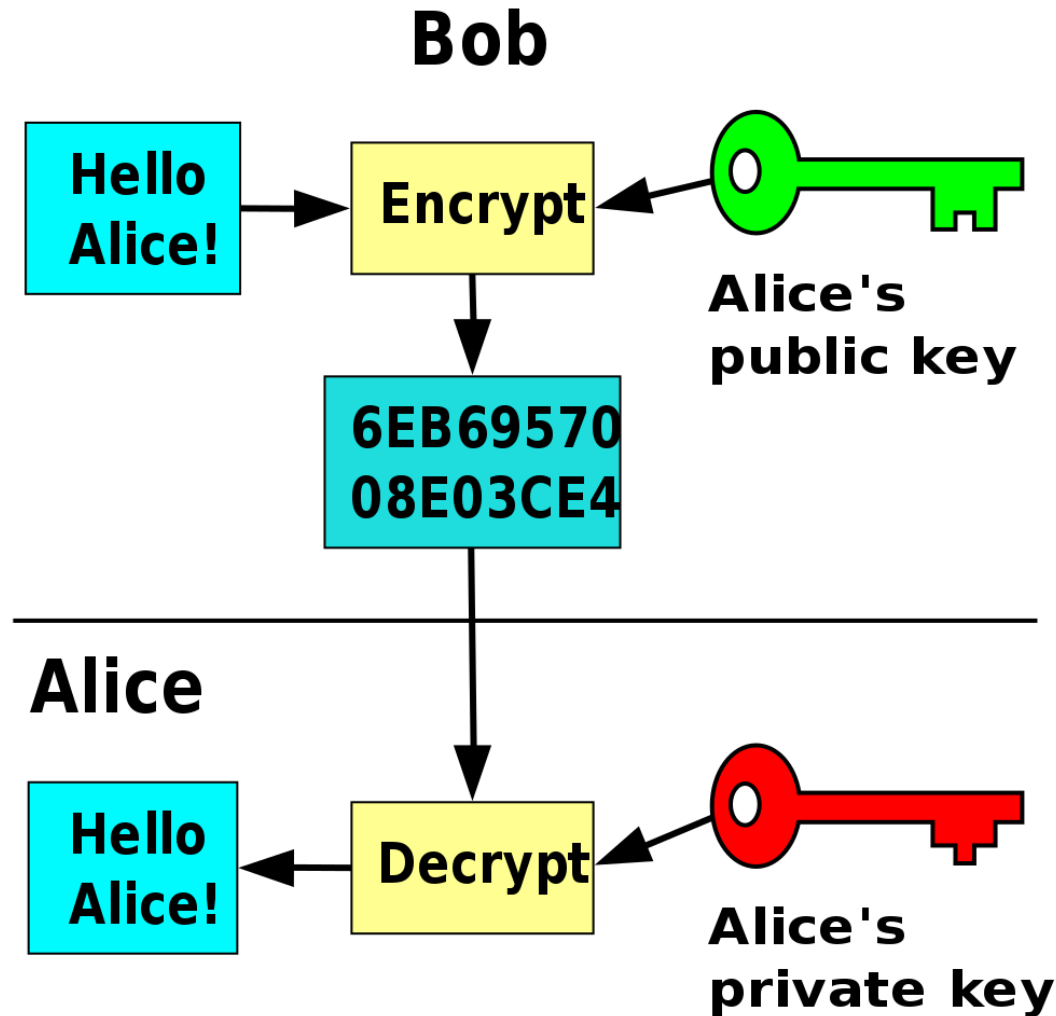
- Also called public-key cryptography
 - Keep private key to yourself and protected
 - Send/share the public key to anyone
- Separate keys for encryption and decryption (public and private key pairs)
- Examples:
RSA,
DSA,
Diffie-Hellman,
El Gamal,
PKCS



Asymmetric Key Encryption

- A data encrypted by a public key is able to decrypt by the corresponding private key
- A data encrypted by a private key is able to decrypt by the corresponding public key
- Therefore Keys are used as,
 - Public key for encryption
 - Private key for decryption
- Secret transmission of key for decryption is not required
- Every entity can generate a key pair and release its public key

Asymmetric Key Encryption



Asymmetric Key Encryption

Two most popular algorithms are RSA & El Gamal

RSA

- Developed by Ron Rivest, Adi Shamir, Len Adelman
- Both public and private key are interchangeable
- Variable Key Size (512, 1024, or 2048 bits)
- Most popular public key algorithm

El Gamal

- Developed by Taher El Gamal
- Variable key size (512 or 1024 bits)
- Less common than RSA, used in protocols like PGP

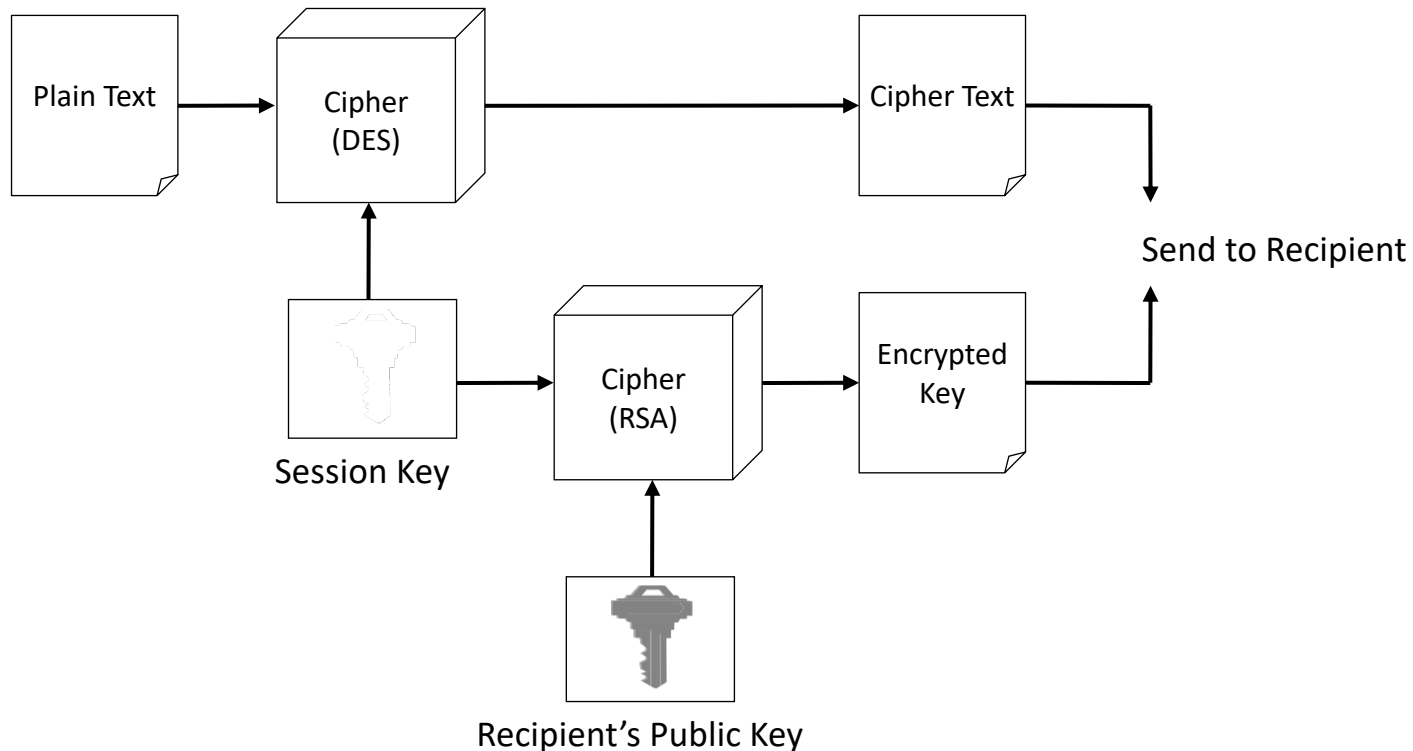
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Cryptographical Applications

Session Key Encryption

Used to improve efficiency

- Symmetric key is used for encrypting data
- Asymmetric key is used for encrypting the symmetric key



SSH

“SSH is a protocol for secure remote login and other secure network services over an insecure network.” – RFC 4251

Secure channel between two computers

Provides data confidentiality and integrity

Many uses other than remote shell

SSH

SSH Transport Layer Protocol

- provides server authentication, confidentiality, and integrity services
- it may provide compression too
- runs on top of any reliable transport layer (e.g., TCP)

SSH User Authentication Protocol

- provides client-side user authentication
- runs on top of the SSH Transport Layer Protocol

SSH Connection Protocol

- multiplexes the secure tunnel provided by the SSH Transport Layer and User Authentication Protocols into several logical channels
- these logical channels can be used for a wide range of purposes
- secure interactive shell sessions
- TCP port forwarding
- carrying X11 connections

SSH

Step 1:

The client opens a connection to the server

Step 2:

Server sends

- Its public host key

- Another public key ("server key") that changes every hour

The client compares the received host key against its own database of known host keys, Can decide to

- Reject keys coming from unknown hosts

- Accept them and store them in its database

SSH

Step 3:

The client

Generates a 256 bit random number using a cryptographically strong RNG (session key)

Picks an encryption algorithm among those supported by the server

Encrypts the session key using both the host key and the server key

Sends the encrypted key to the server

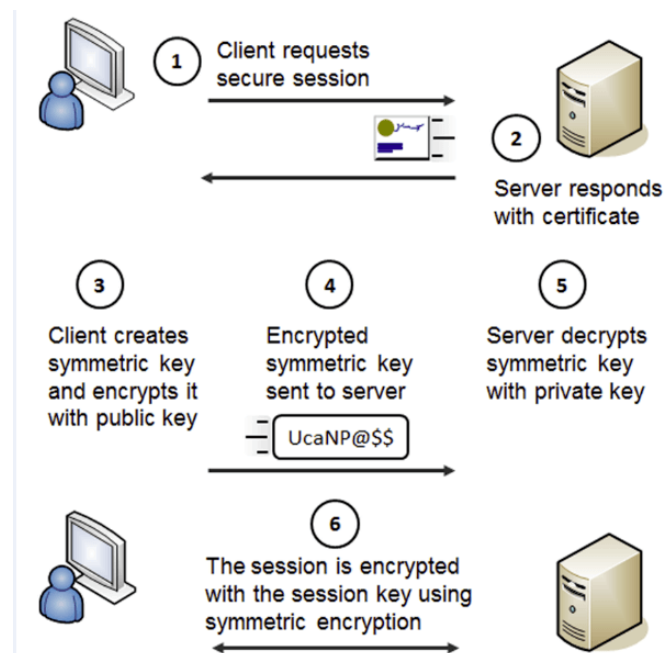
SSH

Step 4:

Server decrypts the session key

Sends an encrypted confirmation to the client showing that it holds the proper private keys

Now client and server can start using transport-level encryption and integrity protection



SSH User Authentication

Protocol assumes that the underlying transport protocol provides integrity and confidentiality (e.g., SSH Transport Layer Protocol)

the protocol has access to the session ID

the server should have a timeout for authentication and disconnect if the authentication has not been accepted within the timeout period

- recommended value is 10 minutes

the server should limit the number of failed authentication attempts a client may perform in a single session

- recommended value is 20 attempts

Several authentication methods are supported

- publickey
- password
- hostbased

SSH User Authentication

We Will look at multiple ways of User Authentication schemes during the tutorials

Message Digest

A message digest is a fingerprint for a document

Purpose of the message digest is to provide proof that data has not altered

Process of generating a message digest from data is called hashing

Hash functions are one way functions with following properties

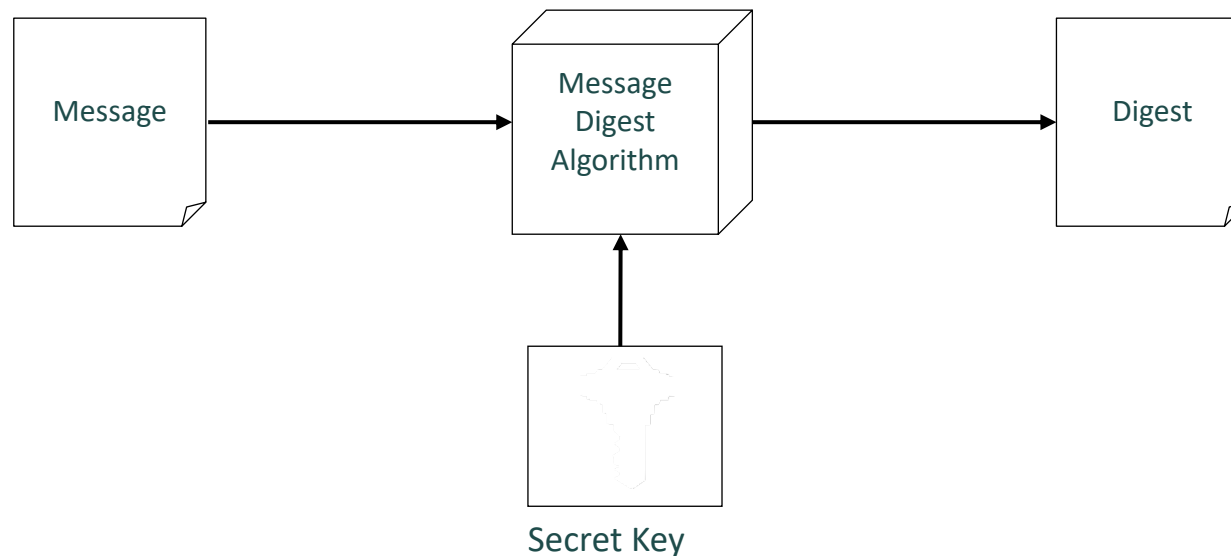
- Infeasible to reverse the function
- Infeasible to construct two messages which hash to same digest

Commonly used hash algorithms are

- MD5 – 128 bit hashing algorithm by Ron Rivest of RSA
- SHA & SHA-1 – 162 bit hashing algorithm developed by NIST

Message Authentication Codes (MAC)

- A message digest created with a key
- Creates security by requiring a secret key to be possessed by both parties in order to retrieve the message



Digital Signatures

A digital signature is a data item which accompanies or is logically associated with a digitally encoded message.

It has two goals

- A guarantee of the source of the data
- Proof that the data has not been tampered with

Digital signing is now used as an accepted means for producing signatures that are considered legally binding in many countries. When a digitally signed message has been received, the receiver has valid reason to believe that the message has originated from the designated sender, even if it has been relayed through a non-secure channel.

Therefore, In many cases, a digital signature is a legally accepted alternative to a handwritten signature or official seal certifying the authenticity of the signature

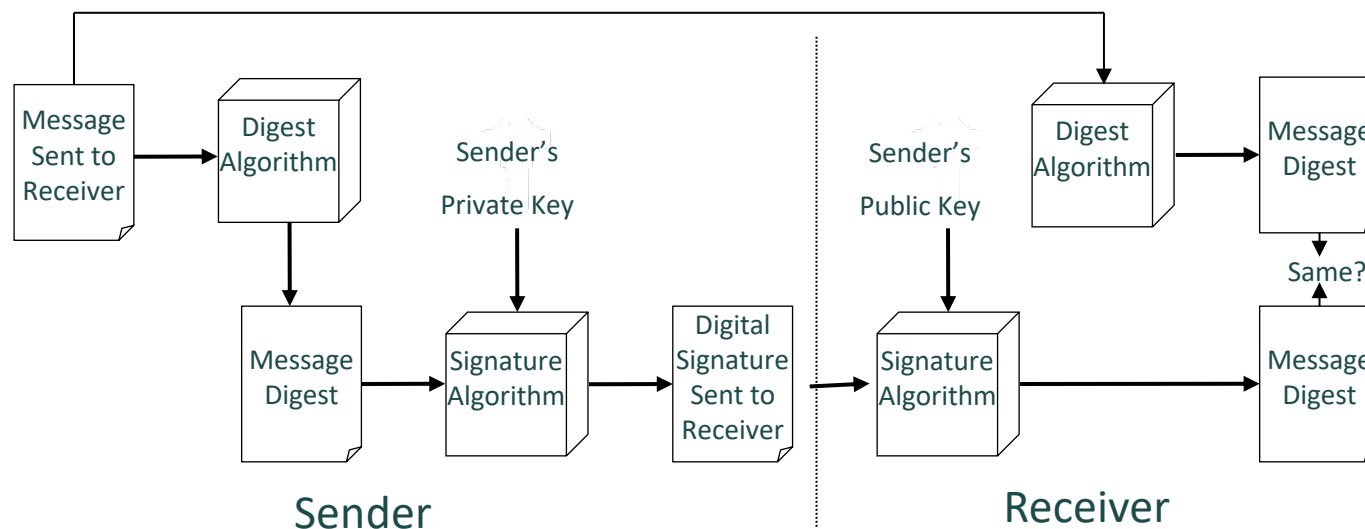
Digital Signatures

There are typically three algorithms involved with the digital signature process:

Key generation – This algorithm provides a private key along with its corresponding public key.

Signing – This algorithm produces a signature upon receiving a private key and the message that is being signed.

Verification – This algorithm checks for the authenticity of the message by verifying it along with the signature and public key.



Pretty Good Privacy - PGP

Let's say Bob want to send a secret message to Alice:

1. Alice has a private key and she has put its connected public key on her web page or a key management public site.
2. Bob download her public key.
3. Bob encrypt his secret message using Alice's public key and send it to her.
4. Only Alice can decode Bob's secret message because she's the only one with the corresponding private key.

Pretty Good Privacy is mostly concerned with the minutiae of creating and using public and private keys. You can create a public/private key pair with it, protect the private key with a password, and use it and your public key to sign and encrypt text.

Pretty Good Privacy - PGP

PGP builds trust upon a web of trust. You don't need to trust the person.

What you need to check is the matching of the person and his/her public key(s)

- You can ask ID cards to confirm the person's name which is usually included in the public key
- And fingerprint of the key to check if the public key you have is actually the key which the person distributed
- Another way trusting is using others trust to trust someone. If some other trusted person says he trusts that person, we can trust that person too. This is called the web of trust.
- Trust is represents by signing the trusted parties public key
- Meaning of someone signing another's public key is that there is a trust built.

PGP Key servers

To make public keys available online, there are pools of public key servers that can be used by anyone. You can search or upload keys. All trusts will be shown as well. (pgp.mit.edu , pool.sks-keyservers.net)

OpenPGPkeyserver

Search for an OpenPGP Public Key, ie 0x..

🔍 Search Key

📤 Submit Key

Advanced Options

```
uid Thilina Pathirana \(Google Mail\) <tdkpl23@gmail.com>
sig  sig3 260A05EB 2015-03-14 _____ [selfsig.]
sig  sig3 6D436CF5 2015-05-24 _____ Udara Sampath Sri Liyanage \(APACHE RELEASE SIGNING KEY\) <udara@apache.org>
sig  sig  0459BBBA 2015-06-02 _____ Sampath Perumbuli \(Personal\) <sperumbuli@gmail.com>
sig  sig  6051EAAC 2016-09-30 _____ Hasitha Gunasekara <hasitha@kln.ac.lk>
sig  sig  D1206993 2018-06-06 _____ Dilum Samarasinghe <dilum@learn.ac.lk>
```



Trusted parties

Example – PGP Encrypted Mail



Thilina Pathirana - LEARN <thilina@learn.ac.lk>

to me ▾

-----BEGIN PGP MESSAGE-----

Charset: utf-8

hQIMA4hzgk7kdZXqAQ/+P82XDwrozH7SS0zK47TrSHW1RPUtwRZTGuMQ+e0Uyler
pCL0j+ybLbYayrJMyJO+/Q33rgu381UXzPcAMQ78pbbsgNLVafhocFiBKvxJsMI0
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HXLQ4WCVIUKr34KjxYCsOGWvc1mymN8BtpFwllUyPwQgYYQS0MqrBix1sEnHMtbu
qgFGZAJSmITTyeo3uklsgBoCghA7WWVUx5PCEUojA8mGAmaPYULixay3LilvpvH5
r2Qilku8/wXSbm62x0AL+I+qy+X8gXPM1bqZHy/kRv6Kso7vGQr7Qzz7J+Uaj/KF
DtBpEtR/ZBsCv71NxEXAzqmB7GzSqEQlua4GNDwirdhw4az//uY7CnpJu17Zr0QY
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sdtzb/no8k8MvOJcJnTaivozQ7RiOcCPMn0AaoVku6V5i/dlejA+jmeosnwLE4iP
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3QpXdLWKpDfIKa2G8scmlEWaeEnqLaPySTCplSY0ukBK2I6LD/UwJ5hscHbfW08
HYxenK0yip9eHW2IWW5E8EC9iNp3Ub9tExiuuGrq1OdAl3hzGUznBcGAq3OJuKxv
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a7GWmn38rgoc/0qXBea9FnY1VV/ohqzaoNq5eDRsBpA+INhEFPxaSf+rTBQ4yX8I
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iNM+BYNuBh/4udi1tYmC7z8Z+fCJH0n0KcLCiO09FnF15k1qoaukQNjo9Yf1eslk
8lrYY9lvTZMwgemFWFfnl4jhQjS4v+TaYM7+XXtlCyXbsTID2wN7g+jyg1jyVT4L
Q/J2FHIjDFuPzoHbOslOEVEJChPf9KYLN3QxxPHhO6DhOdm1p7UL0i/3QdkcDMHPH
VSpFba0fhbHBu5kz/JFwnF1F2eEHv/963fw/5Xg0IUtx0v0bShwsdmVDWjfKuGme
oZv6
=Qq0p
-----END PGP MESSAGE-----

Encrypted Message

Example – PGP Signed Mail

Test PGP



Inbox x



Thilina Pathirana - LEARN

to me ▾

-----BEGIN PGP SIGNED MESSAGE-----

Hash: SHA256

Test Sign

- - -

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-----BEGIN PGP SIGNATURE-----

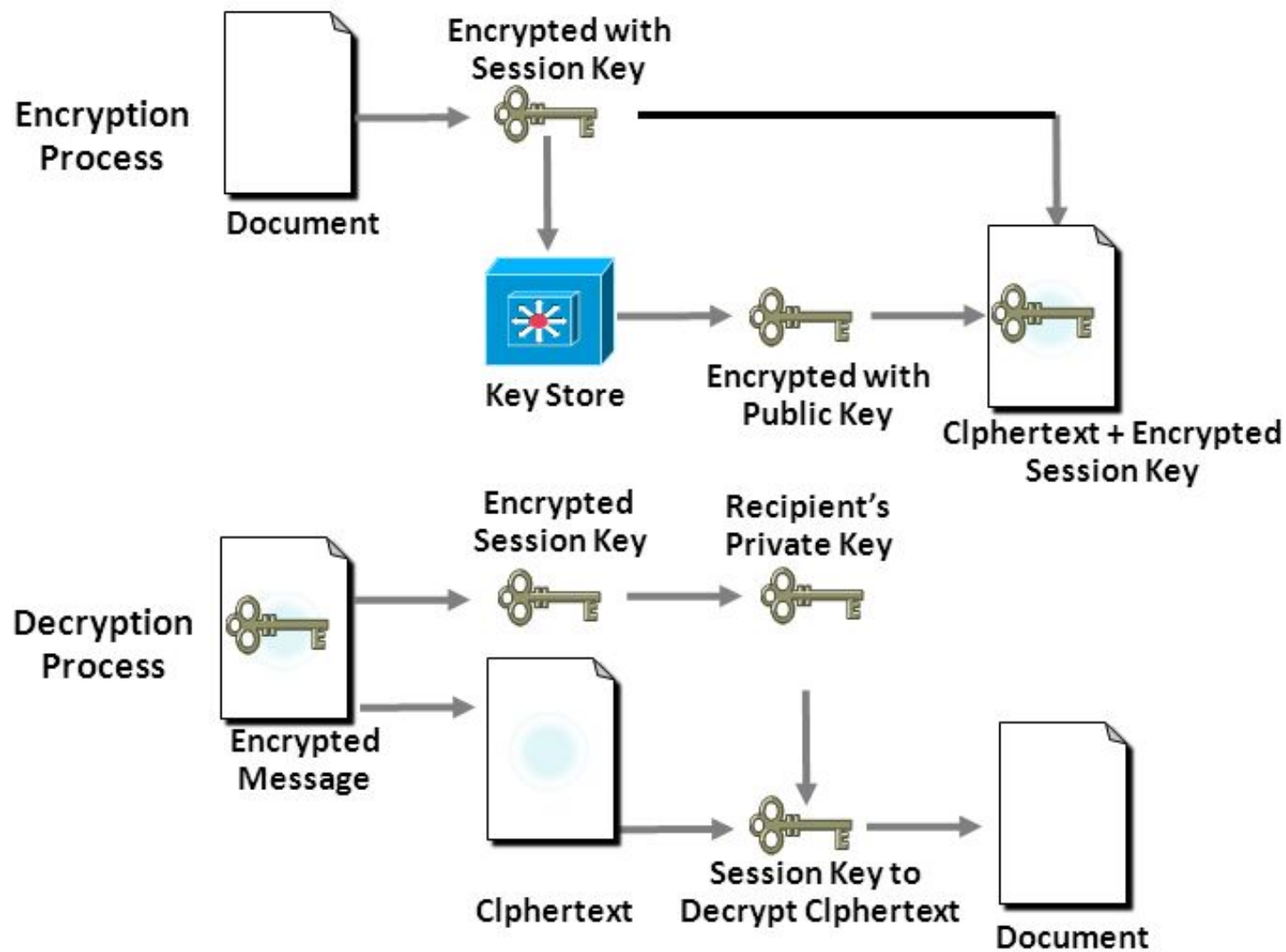
iQEzBAEBCAAAdFiEEe6JDt3GxayDVLJG7Skf3ESYKBesFAIsYEFEACgkQSkf3ESYK
BevQKAf/f9W+cgAKSXVaDXJKJ9Jk7N5N7Kxcq55Z5TmqFlcDX8nAlAfsDQQJ+AJI
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WWjASccH6WUmOMB4iYevEuC5JV/0wWCNza4feABidTFzJ44VNeG11taHWBP4co4K
EcIbL5uNWdGUqExMtNhuBYovWWppuSozY/6/4A/ikJ0dAldormnECD1l8LvumYPG
Ct/jECbM5ltce18eVVI+CsptXIT9g8vKKmfvyJrs+dr5vOTvSnM6NvhfV04urKnY
HERHgsctpYe6scb//xW61FznzN7Rw==
==+qzJ

-----END PGP SIGNATURE-----

Plain text Message

Signature –
Encrypted hash of the
Plain text Message

Example – PGP Process



Digital Certificate

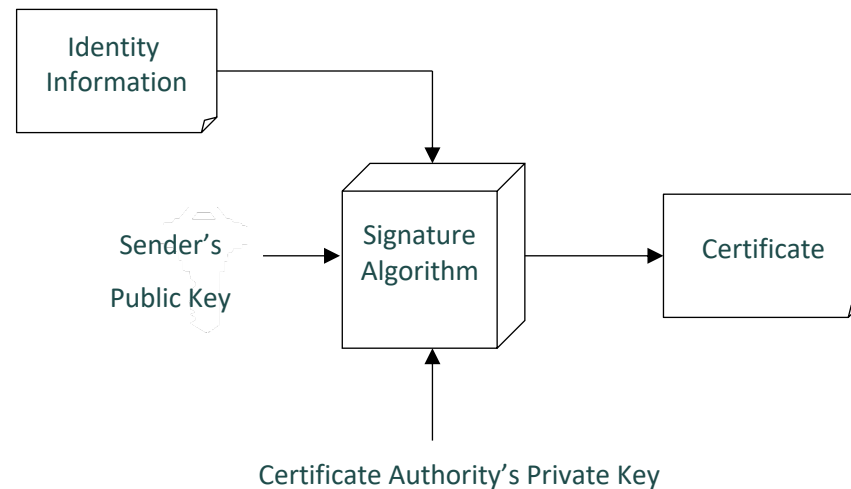
A digital certificate is a signed statement by a trusted party that another party's public key belongs to them.

- This allows one certificate authority to be authorized by a different authority (root CA)

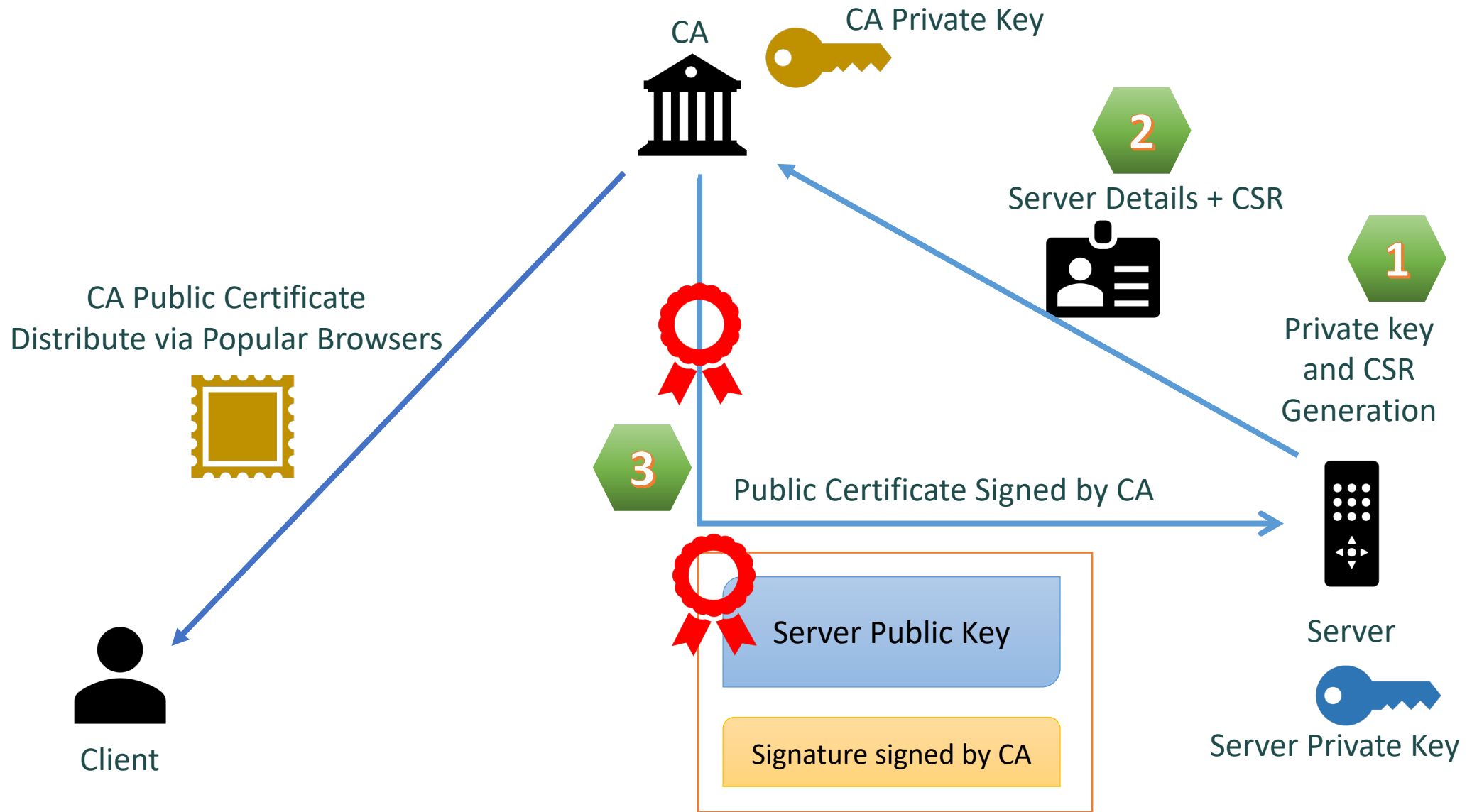
Top level certificate must be self signed

Any one can start a certificate authority

- Name recognition is key to some one recognizing a certificate authority
- Verisign is industry standard certificate authority



HTTPS Process – Certificate Creation



HTTPS Process



Secure/Multipurpose Internet Mail Extensions – S/MIME

This is again a similar protocol like PGP, but the difference is, there is a third party Certificate Authority who entrusts the public key.

When creating S/MIME certificates, you need to get signed your public certificate from a trusted Email CA, therefore we may not need the web of trust as in PGP



Message Is Signed

This message includes a valid digital signature. The message has not been altered since it was sent.

Signed by:

Email address: senevih@learn.ac.lk

Certificate issued by: COMODO RSA Client Authentication and Secure Email CA

[View Signature Certificate](#)

Message Is Encrypted

This message was encrypted before it was sent to you. Encryption makes it very difficult for other people to view information while it is traveling over the network.

Crypto / Digital Currency

- Digital tokens intended to function as medium of exchange (functions of money)
- Based on cryptography to secure creation of tokens/units and perform transactions
- Decentralized control (blockchain): no single issuer comparable to a central bank, collective creation ("mining") and recording of transactions
- Anonymity, possibility to conduct transactions outside the formal banking system and outside government control
- Traded on decentralized exchanges/trading platforms

Crypto / Digital Currency - Bitcoin

- Bitcoin is a software-based payment system described by Satoshi Nakamoto in 2008, and introduced as open-source software in 2009.
- Payments are recorded in a public ledger using its own unit of account, which is also called bitcoin.
- Payments work peer-to-peer without a central repository or single administrator, which has led to identify bitcoin as a decentralized virtual currency.
- Although its status as a currency is disputed in many economies, bitcoin often refers as a cryptocurrency or digital currency.
- Bitcoin transactions are divisible. A satoshi is one millionth of a bitcoin, and it is possible to send a transaction as small as 5430 satoshis on the bitcoin network.

Crypto / Digital Currency - Bitcoin

- There are no bitcoins, only records of bitcoin transactions
- Bitcoins don't exist anywhere, even on a hard drive. We talk about someone having bitcoins, but when you look at a particular bitcoin address, there are no digital bitcoins held in it, in the same way that you might hold money in a bank account. You cannot point to a physical object, or even a digital file, and say "this is a bitcoin".
- Instead, there are only records of transactions between different addresses, with balances that increase and decrease. Every transaction that ever took place is stored in a vast general ledger called the block chain. If you want to work out the balance of any bitcoin address, the information isn't held at that address; you must reconstruct it by looking at the block chain.

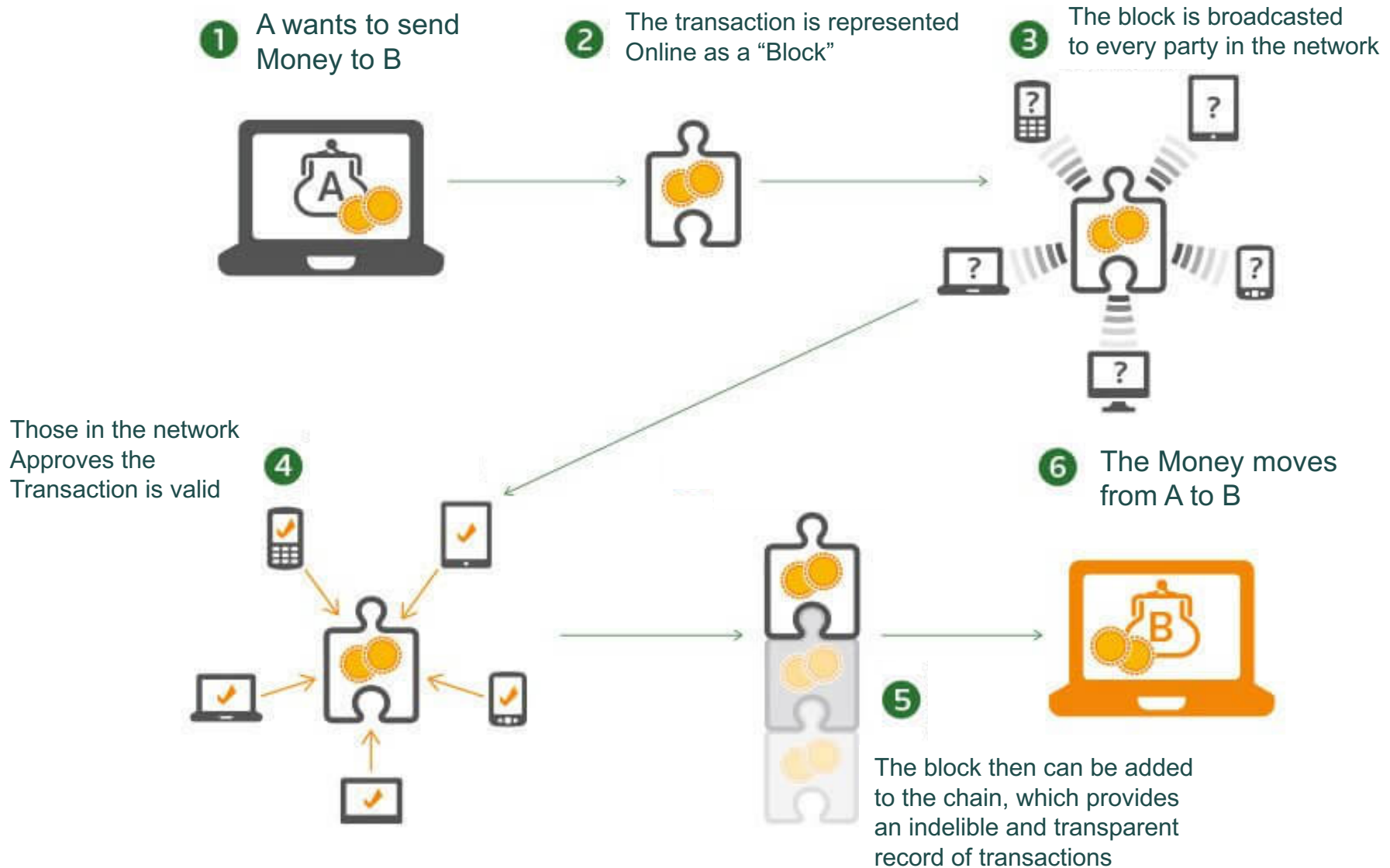
Crypto / Digital Currency - Bitcoin

- To understand mining, one needs to understand what a hash function is. Put simply, a hash function takes an input and creates a seemingly random output, however the output is consistent every time you perform the function on a given input, and it is very difficult to determine an input, given only the output.
- In the calculator, take the square root of 3. You should get 1.73205080756887729352744634150. Now take the digits from the 5th place after the decimal all the way to the 10th place after the decimal. As you can see, its 508075.
- Now try that with another prime number, let's say 11. $\text{sqrt}(11) = 3.3166247903553998491149327366707$, and the digits in place 5 through 10 are: 247903.
- This is basically a very simple (and weak) hash function. If I were to give you the output 512754, what would be the input? If i didn't tell you it was 13, you would have to resort to trial and error to find it. This is Mining.

Crypto / Digital Currency - Bitcoin

- Bitcoin solves the so called “double spending problem” present with digital goods.
- For example, if I have an mp3 file or an ebook on my computer, I can freely copy that file a thousand times and send it to a thousand different people.
- For a digital currency, the possibility for unlimited copying would mean a quick hyperinflationary death.
- Bitcoin solves this by maintaining a peer to peer network and recording each transaction in a public ledger called the block chain. If I send 1 bitcoin from my bitcoin address to my friend Alice. The bitcoin network records that transaction in the block chain and I no longer have possession of that bitcoin. The coin “moved” from my bitcoin wallet to Alice’s wallet.

Crypto / Digital Currency - Bitcoin



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Thank You