



PKI Unlocked: A No-Math Primer for Builders

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Get-ADUser -Identity 'Jake Hildreth'

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- Open-source Toolmaker
- Microsoft MVP:
PowerShell + Identity & Access



Agenda

- History & Goals
- Encoding vs. Encryption
- Symmetric & Asymmetric Encryption
- Hashing Functions
- Signing
- Certificates
- Public Key Infrastructure (PKI)
- Real-World Uses

Non-Agenda

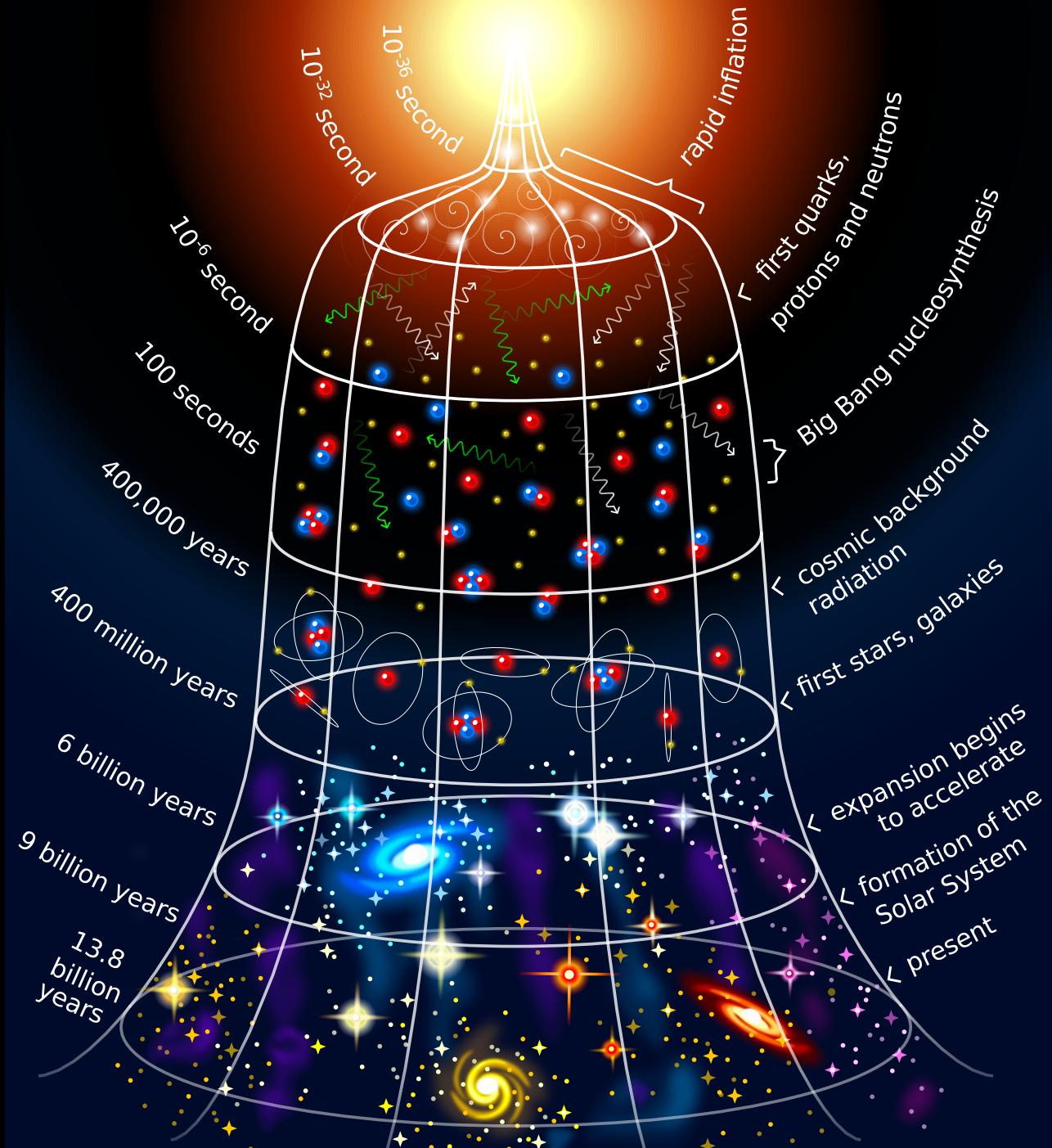
- Cryptocurrency
- Key Exchange
- MAC/HMAC
- Algorithms
- Cryptanalysis
- Key Space
- Steganography
- Active Directory Certificate Services

History

In the beginning was the word...

History

In the beginning was the **password...**



Antiquity

- 1900 BCE: Non-Standard Hieroglyphs
- 1500 BCE: Clay Tablets
- 600 BCE: Hebrew Scholars
- 400 BCE: Polybius Square
- 300 BCE: Kama Sutra
- 196 BCE: Rosetta Stone
- 75 BCE: Caesar Cipher

Medieval

- 750-800 CE: Arabic Scholars
- 800-1100 CE: English Scribes
- 1400 CE: Arabic Scholars
- 1500s CE: Tabula Recta/Vignère Cipher
- 1626 CE: Antoine Rossignol

Pre-WWII

- Focus on Cryptanalysis
- Many Medieval Systems Broken
- First Cryptographic Machines
- First One Time Pad

WWII

- Allies:
 - TypeX, SIGABA, Lacida
- Axis:
 - Enigma, Purple, SG-41

Modernity

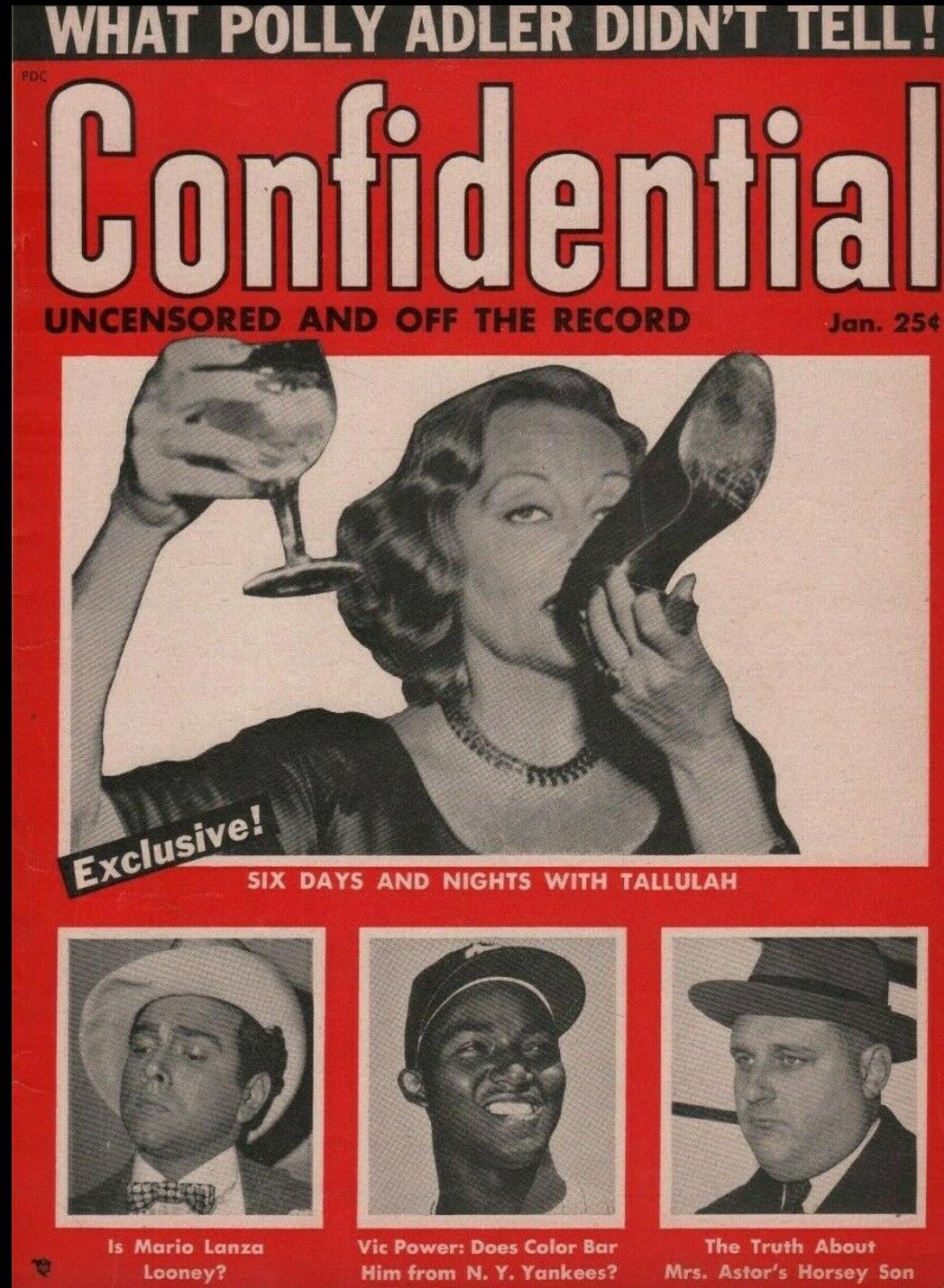
- 1950s: Claude Shannon
- 1975: Data Encryption Standard (DES)
- 1976: Diffie-Hellman (DH)
- 1977: Rivest, Shamir, Adelman (RSA)
- 1989: Message Digest Algorithms (MD*)
- 1991: Digital Signature Algorithm (DSA)
- 1995: Secure Hash Algorithms (SHA)
- 1985-2004: Elliptic Curve Cryptography (ECC)
- 2001: Advanced Encryption Standard (AES)
- The Future: Post-Quantum Cryptography (PQC)



Goals of Cryptography

Confidentiality

Ensures a message is only readable by its intended recipient





Integrity

Ensures a message has not
been tampered with or
changed

Non-Repudiation

Ensures an author cannot refute authorship of a message

I DIDN'T
DO IT!





Authentication

Provides proof an author of a message is who they claim to be

Encoding vs. Encryption

Secret or nah?

Encoding

- Not intended to remain secret
- that is, no **Confidentiality**

Common Schemes

- ASCII
- UTF-8/16/32
- Braille
- Morse Code
- Base64

Example: Cetacean Cipher

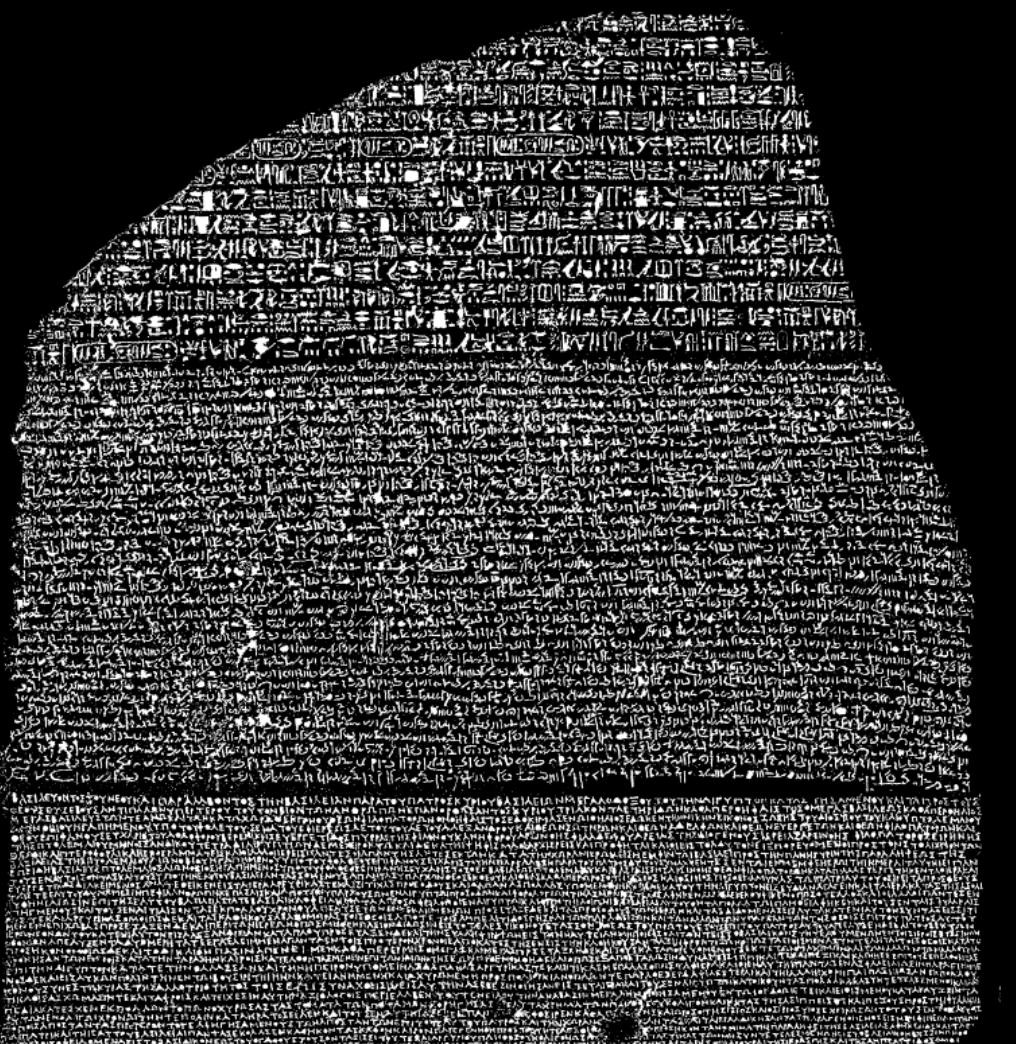
- "Hello, CodeMash!" encoded:
- EEEEEEEEEEeEEeEEEEEEEEEeEEeEe
EEEEEEEEEeEeeEeeEEEEEEEEEeEeeEE
EEEEEEEEEeEeeeEeeEEEEEEEEEeEeeEE
EEEEEEEEEeEEEEeEEEEEEEEEeEeeeEE
EEEEEEEEEeEeeEeeEEEEEEEEEeEeeEE
EEEEEEEEEeEeeEeEEEEEEEEEeEeeEEeE
EEEEEEEEEeEEeeEeEEEEEEEEEeEeeEEEe
EEEEEEEEEeEeeEeeEEEEEEEEEeEeeEEE
EEEEEEEEEeEEEEe

Try it yourself: www.a.tools/Tool.php?Id=389



Example: Rosetta Stone

- Ancient Egyptian was indecipherable
- Rosetta Stone showed Egyptian next to Greek
- Allowed for translating / "decoding" the Egyptian.
- Encoding can be mistaken for encryption - but once the method is known, it is trivial to break.



Encryption

- Intended to remain secret
- Yes! **Confidentiality**
- Requires 1 or more "keys"
- Keys are **something** used to encrypt/decrypt
- In modern cryptography, keys are **really** big numbers
- Kerckhoffs's principle

Common Schemes

- Symmetric - 1 key
 - DES
 - AES
- Asymmetric - 2+ keys
 - RSA
 - ECC

Encrypted data is
indistinguishable from random noise

**Encrypted data ~~is~~ should be
indistinguishable from random noise**



Symmetric Encryption

Pretty much all cryptography before the 1970s

Symmetric Encryption

Pros

- Same key to encrypt/decrypt message
 - Easy to understand
- Simple algorithms
 - Very fast
- Provides **Confidentiality**

Cons

- Keys must be pre-shared via a secure channel before communication
 - Difficult!
- One key per communication group
 - Key management nightmare
- Does not:
 - protect **Integrity**
 - ensure **Non-Repudiation**
 - enable **Authentication**

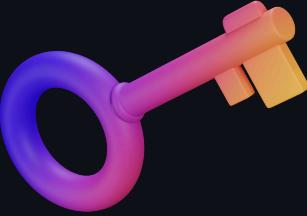
Example: Caesar Cipher (Symmetric)

- Also known as: Shift cipher or ROT*
- Symmetric Encryption $\sim=$ ROT13
 - A(1) + Shift(13) = N(14)
 - N(14) + Shift(13) = A(1)

Original	A	B	C	D	E	F	G	H	I	J	K	L	M
Value	1	2	3	4	5	6	7	8	9	10	11	12	13
"Encrypted"	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

Original	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Value	14	15	16	17	18	19	20	21	22	23	24	15	26
"Encrypted"	A	B	C	D	E	F	G	H	I	J	K	L	M

Example: Caesar Cipher (Symmetric)

Original Message	Alice Encrypts (ROT13)	Encrypted Message	Bob Decrypts (ROT13)	Received Message
Hello, CodeMash!		Uryyb, PbqrZnfu!		Hello, CodeMash!

Try it yourself: <https://rot13.com>

Asymmetric Encryption

Encrypt with one key

Decrypt with a different key

Asymmetric Encryption

Pros

- One **key pair** (public + private) per user
 - Easy(ish) to manage
- Public keys can be shared over insecure channel
 - Much easier than secure channel
- Provides **Confidentiality, Integrity, Non-repudiation**

Cons

- Complicated algorithms
 - Not fast
- No **Authentication** of sender's identity
 - Impersonation is possible

Example: Caesar Cipher (Asymmetric)

- Private Key $\sim=$ ROT7
 - A(1) + Shift(7) = H(8)
- Public Key $\sim=$ ROT19
 - H(8) + Shift(19) = A(1)

Original	A	B	C	D	E	F	G	H	I	J	K	L	M
Value	1	2	3	4	5	6	7	8	9	10	11	12	13
"Encrypted"	H	I	J	K	L	M	N	O	P	Q	R	S	T

Original	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Value	14	15	16	17	18	19	20	21	22	23	24	15	26
"Encrypted"	U	V	W	X	Y	Z	A	B	C	D	E	F	G

Example: Caesar Cipher (Asymmetric)

Original Message	Alice Encrypts (ROT7)	Encrypted Message	Bob Decrypts (ROT19)	Received Message
Hello, CodeMash!		Olssv, JvkIThzo!		Hello, CodeMash!

Try it yourself: <https://rot13.com>

Hash Functions

Neither potatoes nor pipes

Hash Functions

- Maps any data to a (hopefully) unique fixed-length value
- Can't be easily reversed to discover source data
- Changing even a single bit of source data changes the hash
- Ensures **Integrity**

Common Schemes

- MD4/5
- SHA-0/1/2/3
- DSA

Silly Example: Addition + LeftPad

Original	A	B	C	D	E	F	G	H	I	J	K	L	M
Value	1	2	3	4	5	6	7	8	9	10	11	12	13
Original	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Value	14	15	16	17	18	19	20	21	22	23	24	15	26

- HELLOCODEMASH
 - 8+5+12+12+15+3+15+4+5 =
 - Hash: 0079 or 00GI
- HELLO
 - 8+5+12+12+15
 - Hash: 0052 or 00EB
- HELLOCODEMAST
 - 8+5+12+12+15+3+15+4+20 =
 - Hash: 0094 or 00ID

Note: This is a terrible hash function full of collisions. Do not use this for anything.

Real Example #1: Single Character Change

Original	SHA1
Hello, CodeMash!	4edf8a86e11c4adb7839e9940666ce882f563cc
Hello, CodeMast!	2d6ea1719370b90fab69e08bc5dea3bd7c77b4e6

Try it yourself: <https://gchq.github.io/CyberChef>

Real Example #2: Variable-Length -> Fixed Length

Original	SHA1
The quick brown fox jumps over the lazy dog.	408d94384216f890ff7a0c3528e8bed1e0b01621
The quick brown fox jumps over the lazy dog. (x100)	b09876f717b413763e960238754c6f22d2143ac2
The quick brown fox jumps over the lazy dog. (x200)	1f75bf99415e85c75fde244ec71de7f5e2d226ba

Try it yourself: <https://gchq.github.io/CyberChef>

Signing

Hashing + Asymmetric Encryption = Better Than Ink

Signing Process

- Alice creates a message
- Alice creates a hash of her message
- Alice encrypts **the hash** with her **private key**
- Alice sends package to Bob
- Bob simultaneously:
 - decrypts hash w/ Alice's **public key**
 - hashes the original message
- If hashes match, Alice is the sender!

Common Uses

- Used for **Non-repudiation**
- Software distribution
- Financial transactions
- Contract management
- Network protocols

Example: Addition (Hashing) + Caesar Cipher (Asymmetric Encryption)

Original Message + Hash	Alice Encrypts Hash (ROT7)	Original Message + Encrypted Hash	Bob Decrypts Hash (ROT19)	Original Message + Decrypted Hash	Bob Hashes Message Himself
"Hello, CodeMash!" Hash: 00GI		"Hello, CodeMash!" Encrypted Hash: 00TV		"Hello, CodeMash!" Decrypted Hash: 00GI	"Hello, CodeMash!" Hash: 00GI MATCH!

Certificates

Public Key and Attributes, Signed... by someone!

Certificates

- Public keys don't include identifying information
- Certificates tell who owns a public key
- Certificates provide basic **Authentication**
- **If** you trust the issuer, you can trust the public key
- Self-signed certs still permit encryption!

Typical Contents

- Subject
- Issuer
- Public Key
- Not Before/Not After
- Key Usage/Extended Key Usage
- Signature Algorithm/Signature
- Serial Number

Generating a Self-Signed Certificate

Create a Key Pair	Create CSR	Hash the CSR	Encrypt Hash w/ Alice's Private Key	Package Certificate
 	Subject: Alice Public Key: 	OBHF	OUAY	Subject: Alice Issuer: Alice Public Key:  Signature Algorithm: Silly Signature: OUAY

Certification Authority (CA) Certificate Generation

Create a Key Pair	Create CSR	Hash the CSR	Encrypt Hash w/ CA's Private Key	Package Certificate
 	Subject: Alice Public Key: 	0BHF	OKQO	Subject: Alice Issuer: CA Public Key:  Signature Algorithm: Silly Signature: OKQO

Public Key Infrastructure (PKI)

Formalized trust - all the way down to the root

PKI Basics

- Not **just** technology:
 - Hardware
 - Software
 - Policies
 - Procedures
- "Chains" of trust lead back to a "root" of trust
- **If** you trust the PKI (big if), you can trust others that use the PKI

Common Components

- Authorities:
 - Root/Intermediate/Issuing
 - Validation
 - Registration
 - Policy
 - Timestamp
- Users:
 - End Entities
 - Relying Parties

How Do I Know If I Should Trust a PKI?

How Do I Know If I Should Trust a PKI?



How Do I Know If I Should Trust a PKI?

- Mostly handled for you
- OSes include lists of trusted roots
 - They're also usually out of date - Server 2025 GA included 7 Root CAs that were expired.
- Active Directory (AD) networks have PKI: AD Certificate Services
 - Drink!
- Reputable PKIs publish their configurations and procedures
- Honestly, something I need to dig into...

Real-World Uses

Hybrid Cryptosystems - **VERY** Simplified

Pretty Good Privacy (PGP)/GNU Privacy Guard (GPG)

Encryption Process

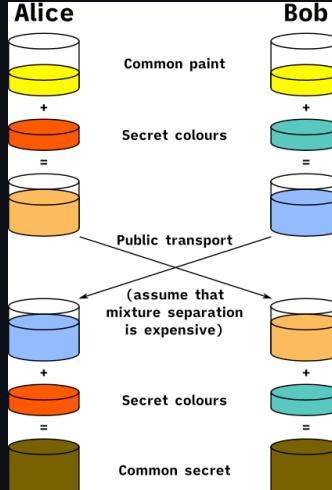
Alice Writes a Message & Creates a Session Key	Alice Encrypts the Message with the Session Key	Alice Encrypts The Session Key With Bob's Public Key	Alice Combines the Encrypted Message and Session Key And Sends to Bob
Message: "Hello, CodeMash!" Session Key: 4dyea1wo	Encrypted Message: "Fcjjm, YlrgAyqr!"	Encrypted Session Key: 7tjtf57d	Encrypted Message: "Fcjjm, YlrgAyqr!" Encrypted Key: 7tjtf57d

PGP/GPG

Decryption Process

Bob Receives the Encrypted Package	Bob Decrypts The Session Key With His Private Key	Bob Decrypts the Message with the Session Key
Encrypted Message: "Fcjm, YlrgAyqr!" Encrypted Key: 7tjtf57d	Decrypted Key: 4dyea1wo	Decrypted Message: "Hello, CodeMash!"

Secure Sockets Layer (SSL)/Transport Layer Security (TLS)

Client Contacts Server via HTTPS	Server Sends Certificate for Client to Validate	Server and Client Agree on a Session Key (Diffie-Helman)	Data Stream is Encrypted with Session Key
dotdot.horse	Name: dotdot.horse Issuer: CA Signature: Signature	 <p>The diagram illustrates the Diffie-Hellman key exchange protocol using paint as an analogy. It shows two parties, Alice and Bob, each with a set of colored containers. Alice starts with a "Common paint" container (yellow) and adds "Secret colours" (orange). She then performs "Public transport" to mix the colors. Bob starts with his own "Common paint" (yellow) and adds "Secret colours" (cyan). Both parties then perform "mixture separation" (represented by arrows pointing from the mixed containers back to the original secret colors). This process results in both parties having a "Common secret" (green) which they can use for encryption.</p>	

Quick Review

Quick Review

- Humans have wanted to hide things **forever**
- Encoding is reversible **w/o keys**
- Encryption is reversible **with keys**
 - Symmetric Encryption:
 - Uses 1 key
 - FAST
 - Asymmetric Encryption:
 - Uses 2+ keys
 - SLOW
- Hashing is not reversible
- Signing combines hashing and encryption to provide non-repudiation
- Certificates bind an identity to a public key
- PKI solves a lot of problems... but at a cost
- Most modern cryptosystems combine symmetric and asymmetric encryption, hashing, signing, and certificates!

Resources

github.com/jakehildreth/CodeMash26

Links

Cetacean Cipher: a.tools/Tool.php?id=389

CyberChef: gchq.github.io/CyberChef

Caesar Cipher: rot13.com



Thanks, CodeMash!

Find	Me
LinkedIn	linkedin.com/in/jakehildreth
GitHub	github.com/jakehildreth
Site	jakehildreth.com

