Who Moved my Rock?

Post-Quantum Cryptography and
its Impact on Higher Education

Who am I?

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Chief Information Security Officer

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INTEGRITY
AVAILABILITY
CONFIDENTIALITY
IAS

Quantum Computers Could Crack Encryption Sooner Than Expected With New Algorithm

By **Edd Gent** › October 2, 2023

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December 7, 2023

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China's new quantum code-breaking algorithm raises concerns in the US

The new algorithm could render mainstream encryption powerless within years.

Baba Tamim

Published: Jan 12, 2023 06:56 AM EST

INNOVATION

Euro Security Watch with Mathew J. Schwartz

Tracking security and privacy trends across UK, Europe and beyond

Encryption & Key Management , Security Operations

Researcher Claims to Crack RSA-2048 With Quantum Computer

As Ed Gerck Readies Research Paper, Security Experts Say They Want to See Proof

Mathew J. Schwartz (euroinfosec) • November 1, 2023

Member-only story

NASA Just Shut Down Quantum Computer After Something Insane Happened!

Top highlight

Houston, We Have a Problem!

The Pareto Investor · Follow

3 min read · Nov 9

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Guest Post: Harvest Now, Decrypt Later? The Truth Behind This Common Quantum Theory

Insights Jeffrey Duran • February 7, 2023

Paper 2024/555

Quantum Algorithms for Lattice Problems

Yilei Chen , Tsinghua University, Shanghai Artificial Intelligence Laboratory, Shanghai Qi Zhi Institute

Abstract

We show a polynomial time quantum algorithm for solving the learning with errors problem (LWE) with certain polynomial modulus-noise ratios. Combining with the reductions from lattice

Meta

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Chinese Researchers Tap Quantum to Break Encryption

But the time when quantum computers pose a tangible threat to modern encryption is likely still several years away.

Jai Vijayan, Contributing Writer
October 16, 2024

4 Min Read

SOURCE: FUNTAP VIA SHUTTERSTOCK

Researchers at China's Shanghai University have demonstrated how quantum mechanics could pose a realistic threat to current encryption schemes even before full-fledged quantum computers become available.

The researchers' paper describes how they developed a working RSA public key cryptography attack using D-Wave's Advantage quantum computer. Specifically, the researchers used the computer to successfully factor a 50-bit integer into its prime factors, thereby giving them a way to derive private keys for decryption.

Editor's Choice

OWASP Beefs Up GenAI Security Guidance Amid Growing Deepfakes

by Robert Lemos, Contributing Writer

NOV 4, 2024 5 MIN READ

How to Win at Cyber by Influencing People

by Gregory R. Simpson

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TECHNOLOGY

Google has just crossed the quantum threshold: thus begins the era of error-free computers

By Adrian Villellas

Published On: February 9, 2026 at 10:15 AM

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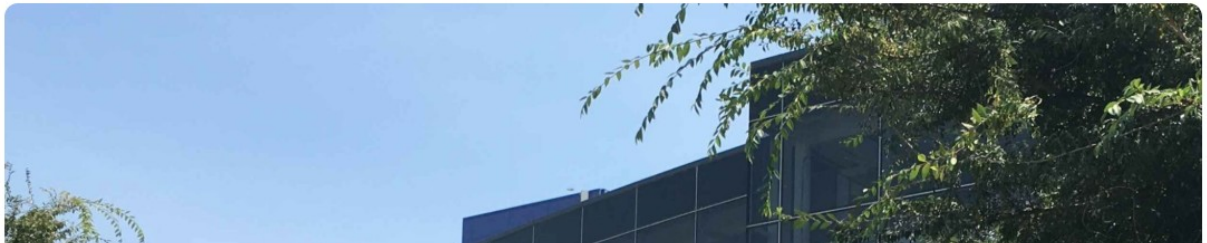


Latest news

At a depth of 100 meters underground in Albania, scientists have just discovered a thermal lake so large that it challenges our understanding of the world

Published On: February 17, 2026 at 8:45 AM

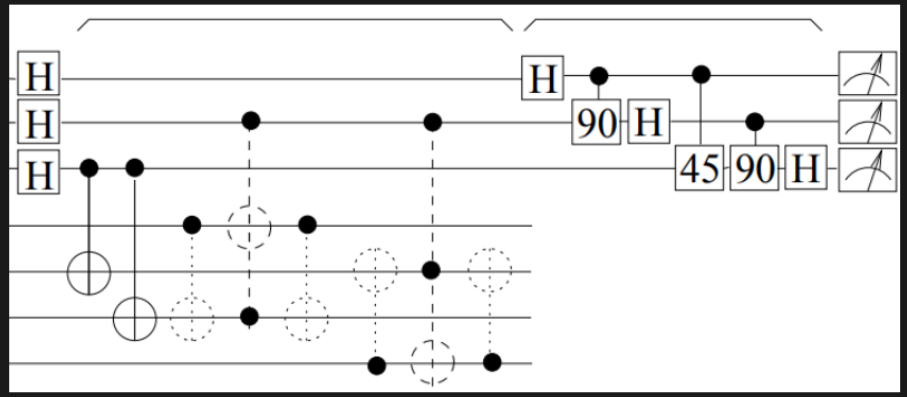
An iconic Chicago candy factory with nearly 100 years of history has filed for bankruptcy and could close permanently after losing millions

WHY HAVEN'T QUANTUM COMPUTERS FACTORED 21 YET?

by: Maya Posch

36 Comments

February 9, 2026



If you are to believe the glossy marketing campaigns about 'quantum computing', then we are on the cusp of a computing revolution, yet back in the real world things look a lot less dire. At least if you're worried about quantum computers (QCs) breaking every single conventional encryption algorithm in use today, because at this point they cannot even factor 21 yet without cheating.

SEARCH

Characters

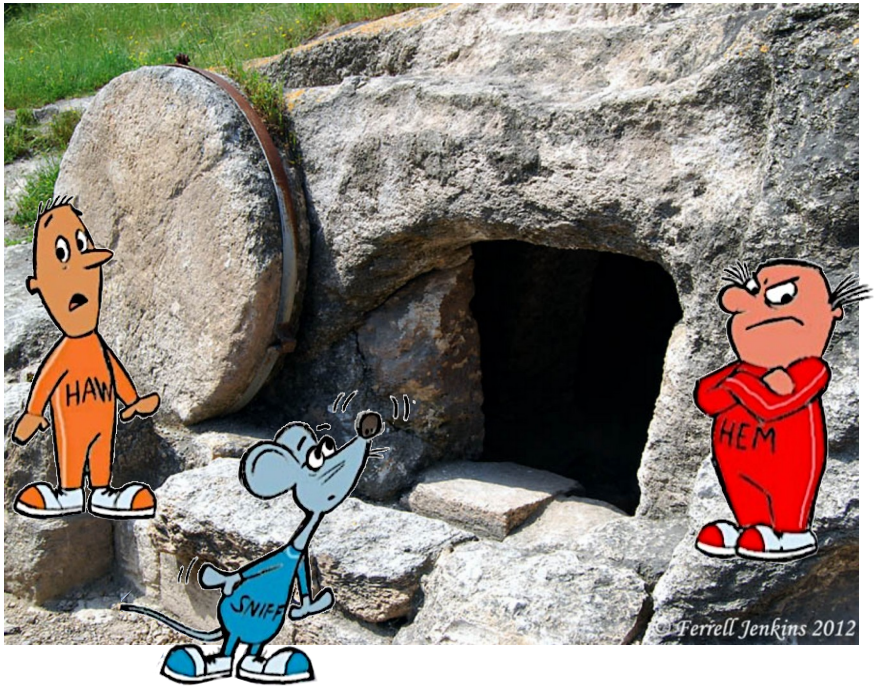
Hem - angry, impatient, unwilling to move

Haw - scared stiff, but thinks

Sniff - always using their tools

Scurry - always on the move to discover new things

Protecting things

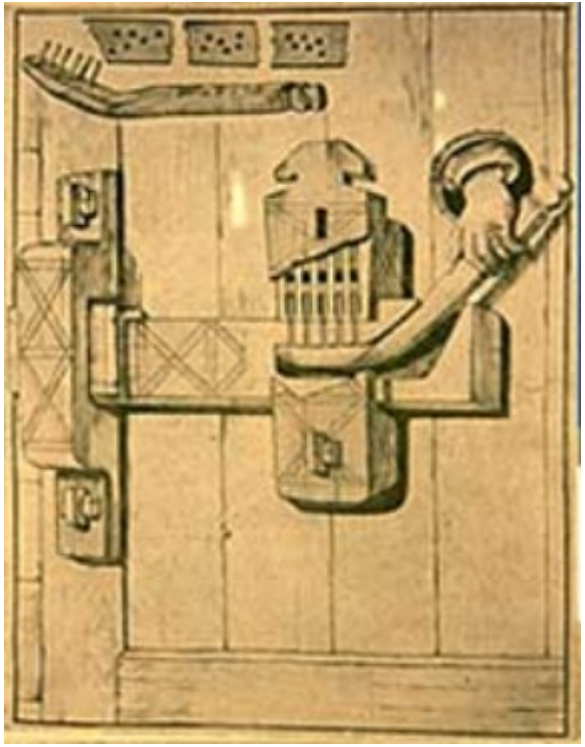


First Attempt at Security

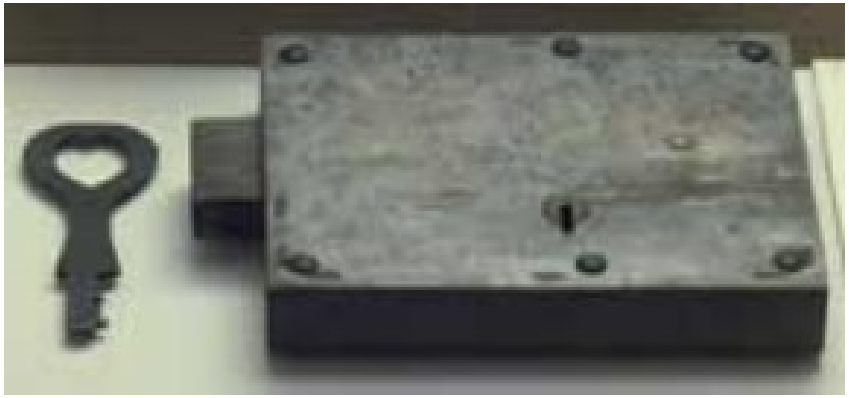
- Put large boulders in front of our caves
- Someone figured out how to move them
- Repetitive journey - find the better lock

Protectors

Locks and Lockpicks



Locks and Lockpicks



Value of things and information

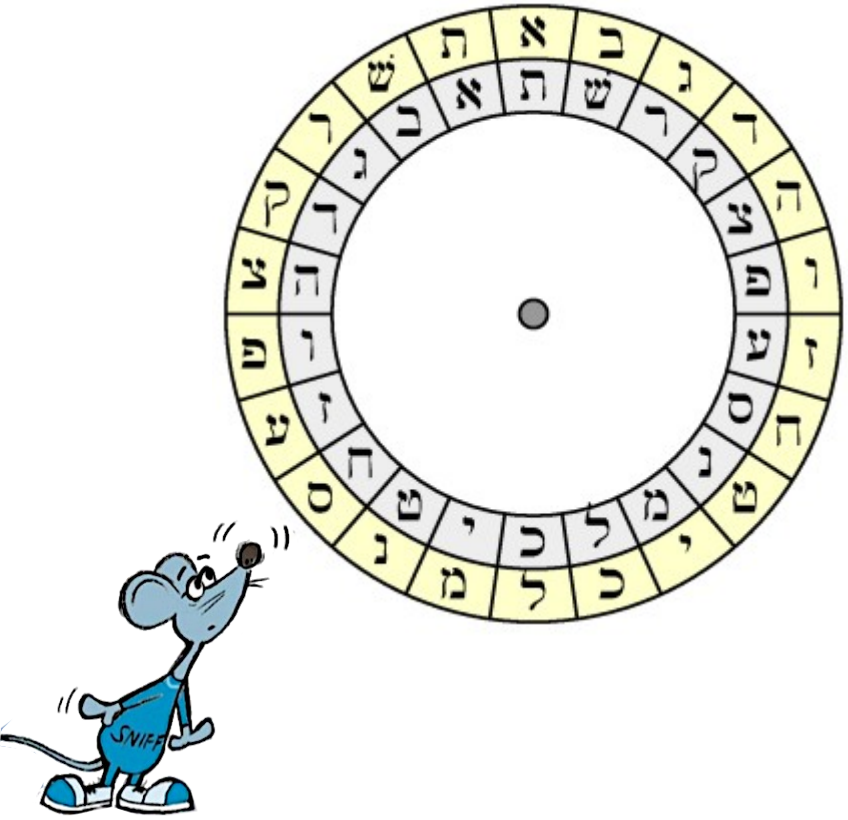
- Information became valuable
  - War plans
  - Hidden treasure
  - Hunting / farming grounds
- Necessary to transmit
  - Get strategy to front lines
  - Remote allies
- Easy to intercept

Hiding info in plain sight

- Novel schemes
- Useless when discovered
- Secrets can be bought

Hiding info in plain sight

Encoding


SNIFF

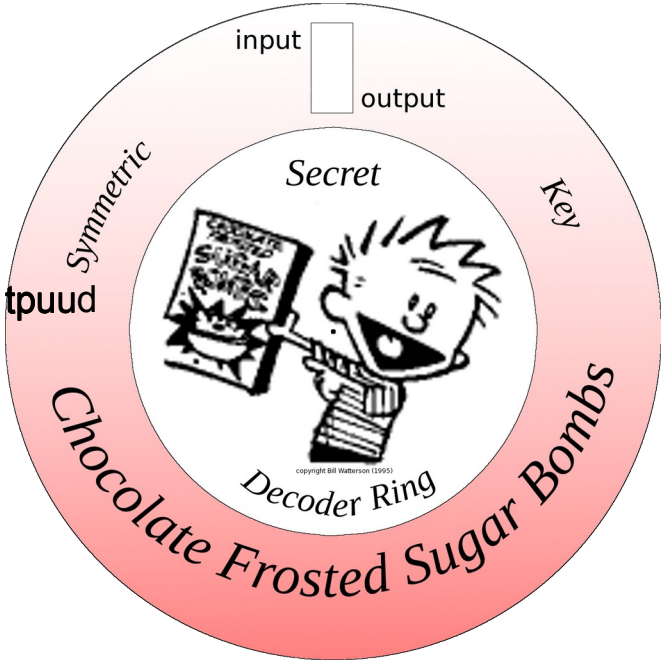

I II III IV V
I A B C D E
II F G H IJ K
III L M N O P
IV Q R S T U
V V W X Y Z
PREPARE FOR ATTACK

Symmetric Key Cryptography

- Single key for both encryption and decryption
- Simple
- Powerful
- Key distribution issues
- Number of keys difficult

Symmetric Key Cryptography

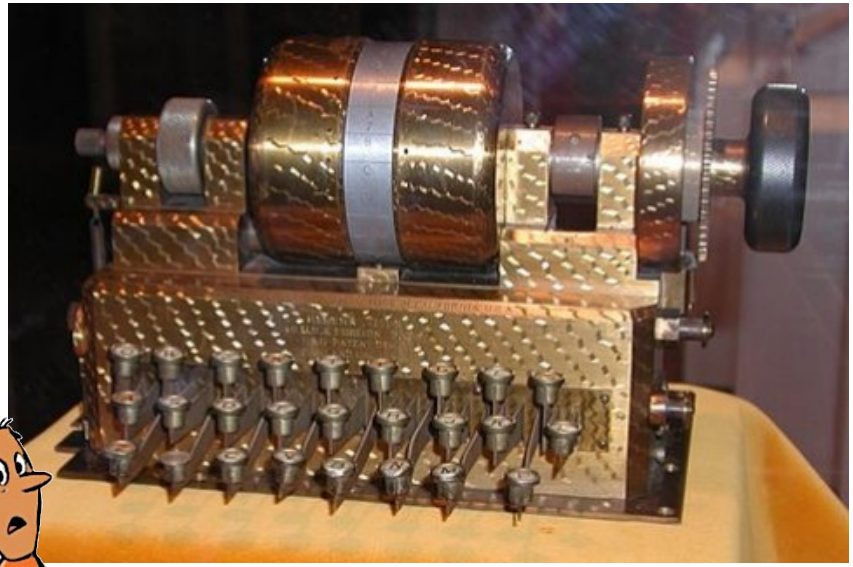
tpuud

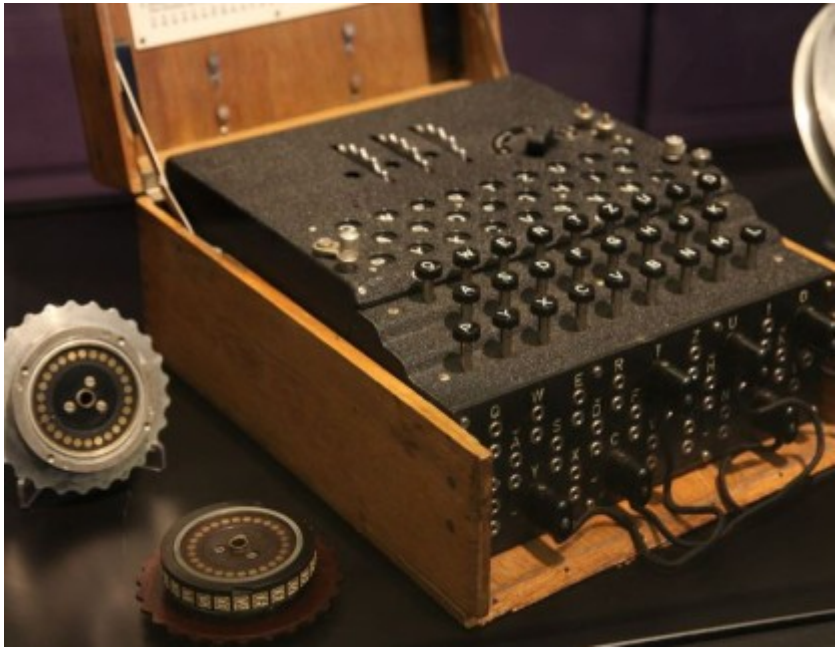


tpuud

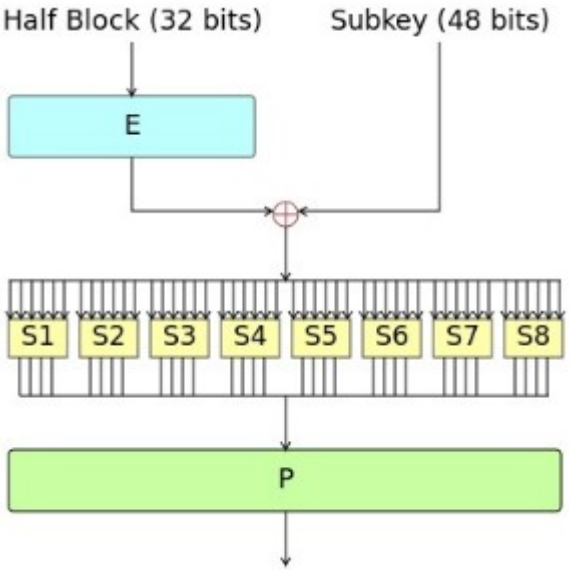
Jimmy

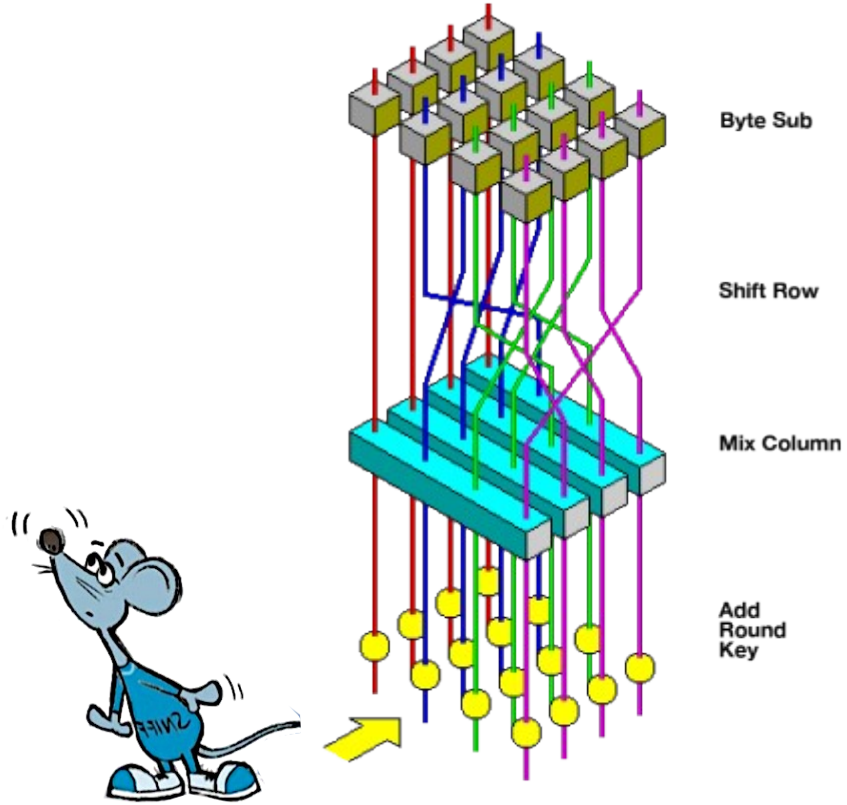
Symmetric Key Cryptography



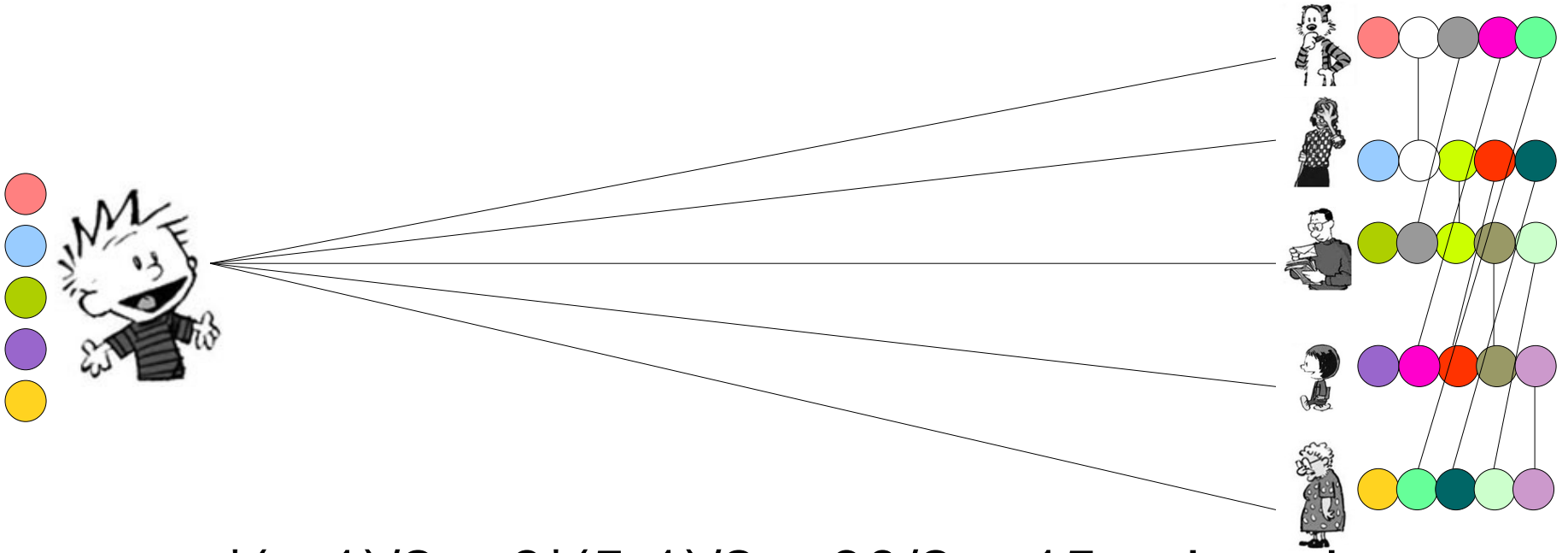


Symmetric Key Cryptography





Symmetric Key Cryptography

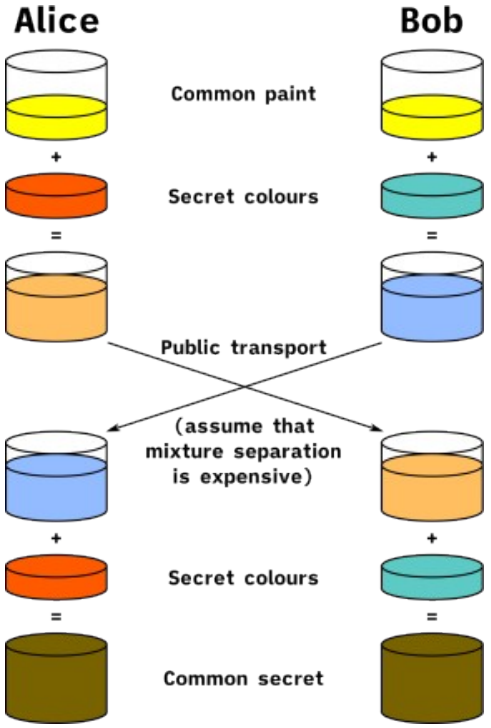


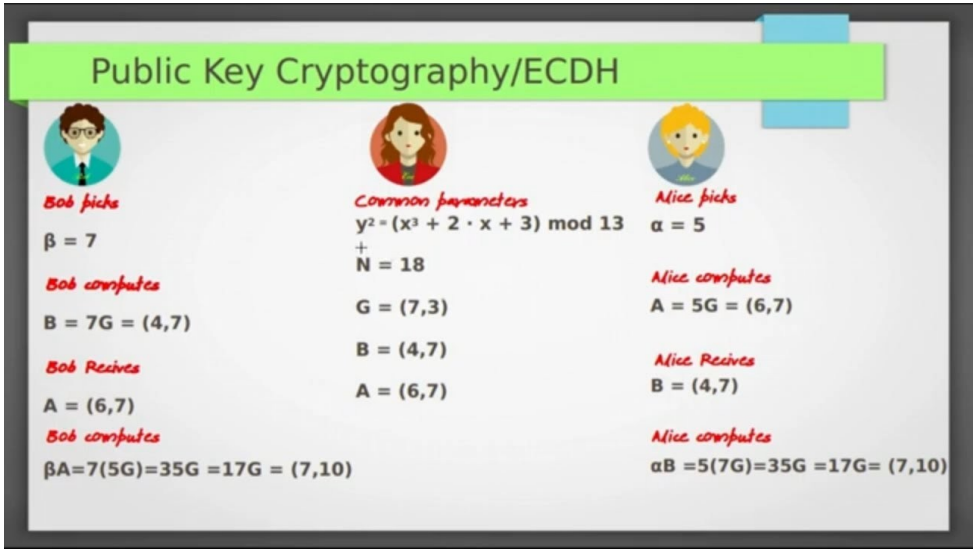
$n*(n-1)/2 = 6*(5-1)/2 = 30/2 = 15$ unique keys

Key Exchange

- Generate a unique secret key
- Never transfer it over the wire

Key Exchange (Diffie-Hellman)

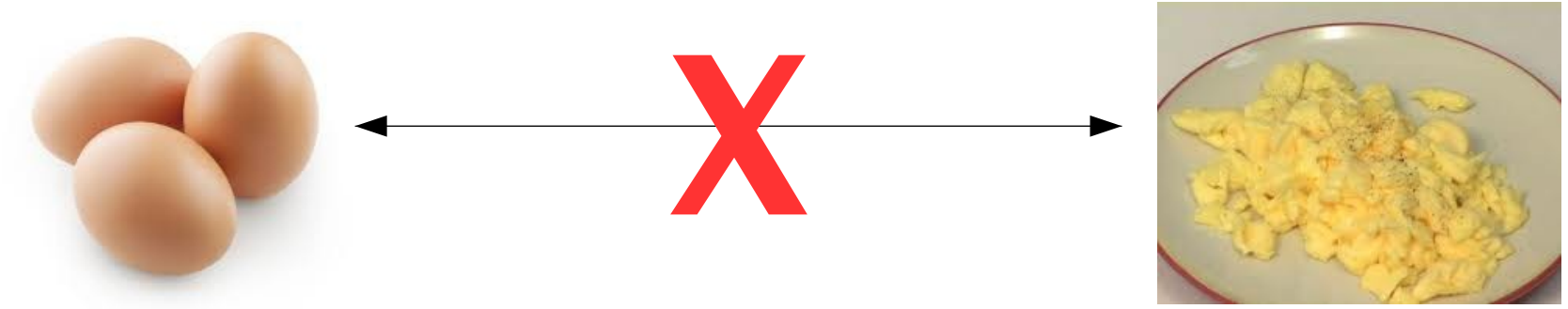




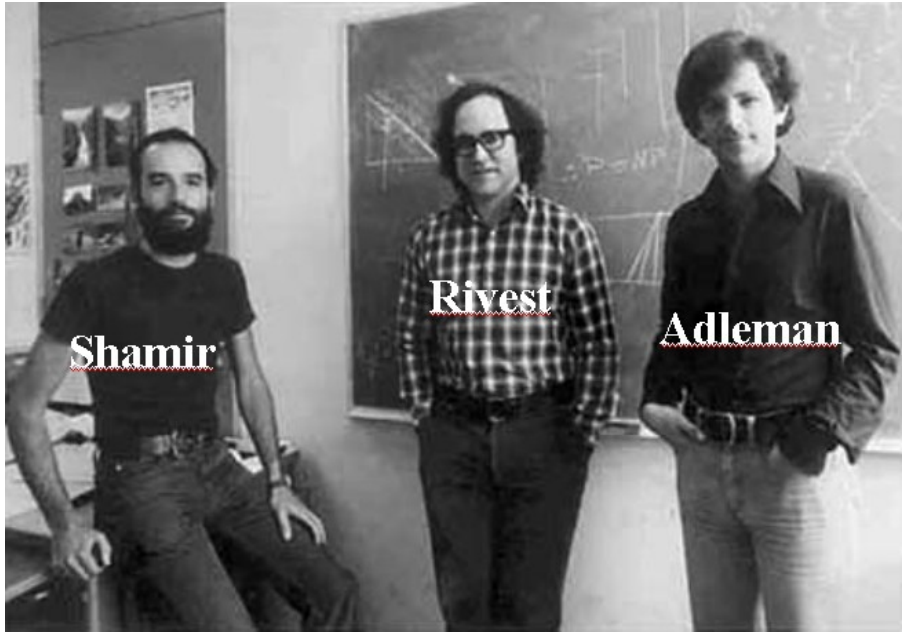
Asymmetric Key Cryptography

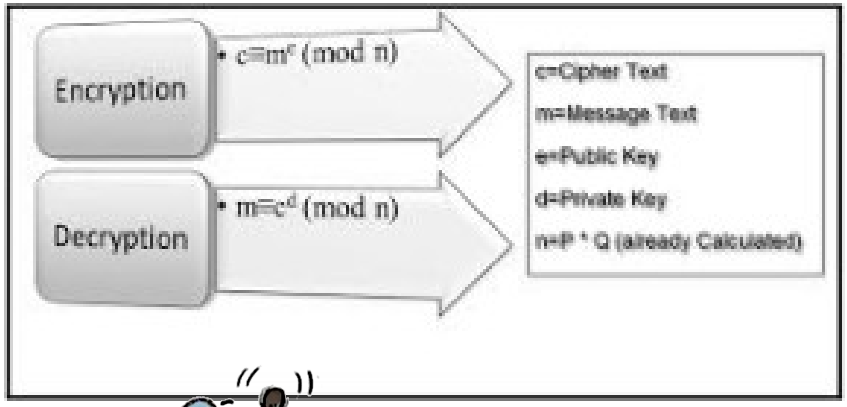
- Split public and private keys
- Key distribution easier
- Number of keys manageable
- Slower
- Authentication issues
- Relies on a one-way function (Theoretical Math)

One way function



RSA

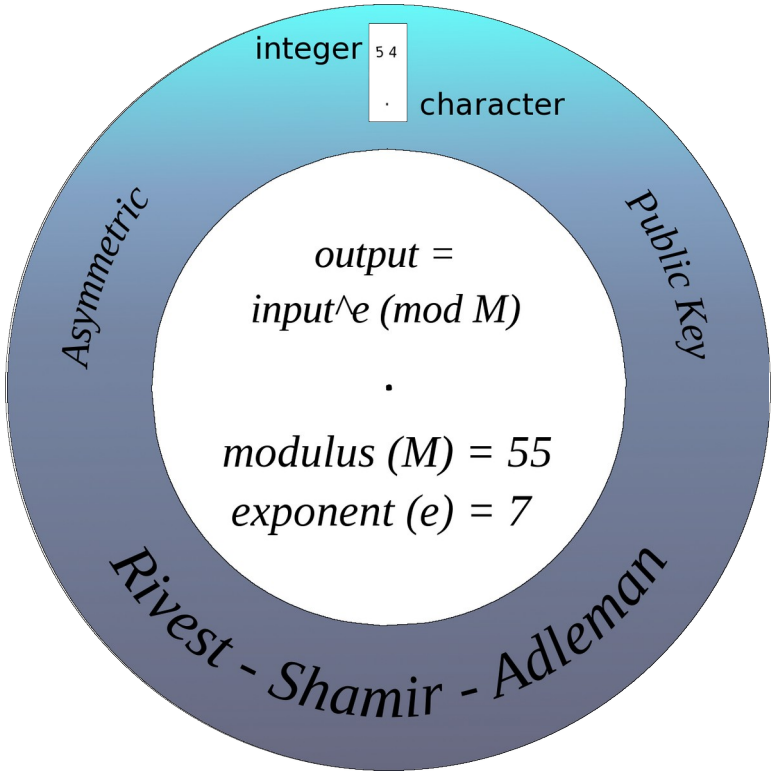

Shamir
Rivest
Adleman


Encryption
c=m^e (mod n)
Decryption
m=c^d (mod n)
c=Cipher Text
m=Message Text
e=Public Key
d=Private Key
n=P * Q (already Calculated)


SNIFF

One way function for RSA

Jimmy



14 13 18 18 36

One way function for RSA

14 13 18 18 36

14 13 18 18 36

One way function for RSA

11 14 13 18 18 36

13

18

18

36

One way function for RSA

$14^7 \bmod 55 = 105413504 \bmod 55 = 9 = \text{“g”}$

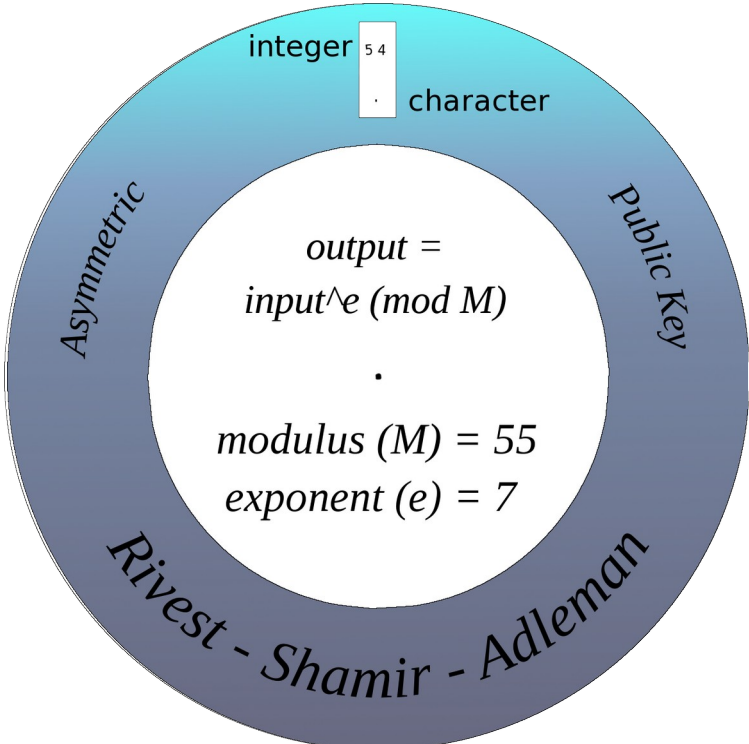
$13^7 \bmod 55 = 7 = \text{“e”}$

$18^7 \bmod 55 = 17 = \text{“l”}$

$18^7 \bmod 55 = 17 = \text{“l”}$

$36^7 \bmod 55 = 31 = \text{“v”}$

E(Jimmy) = gellv



One way function for RSA

$9^{23} \bmod 55 = 14 = \text{“J”}$

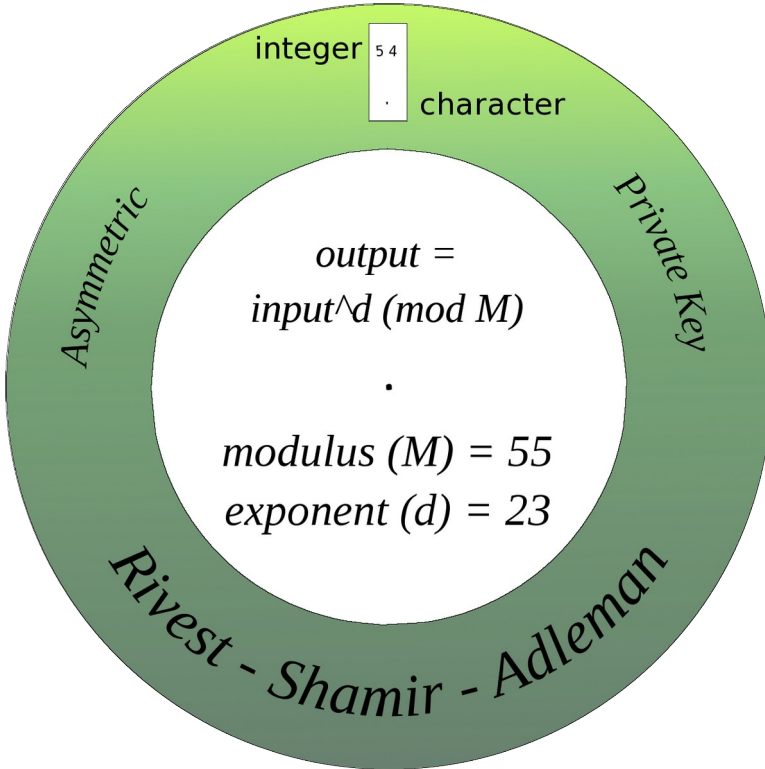
$7^{23} \bmod 55 = 13 = \text{“i”}$

$17^{23} \bmod 55 = 18 = \text{“m”}$

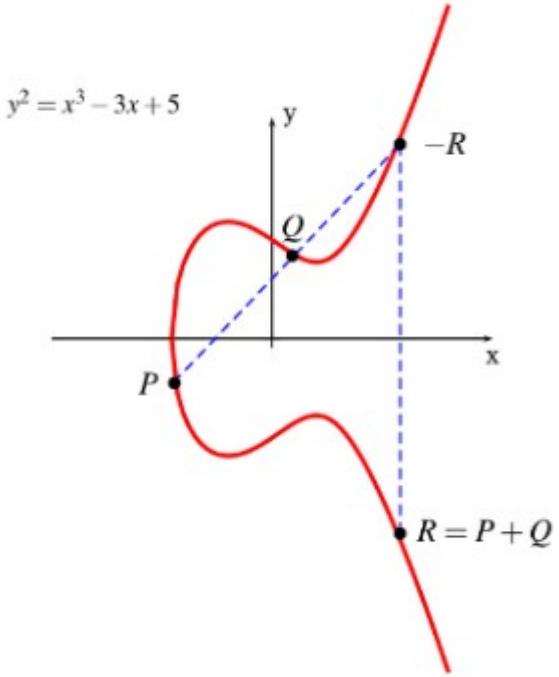
$17^{23} \bmod 55 = 18 = \text{“m”}$

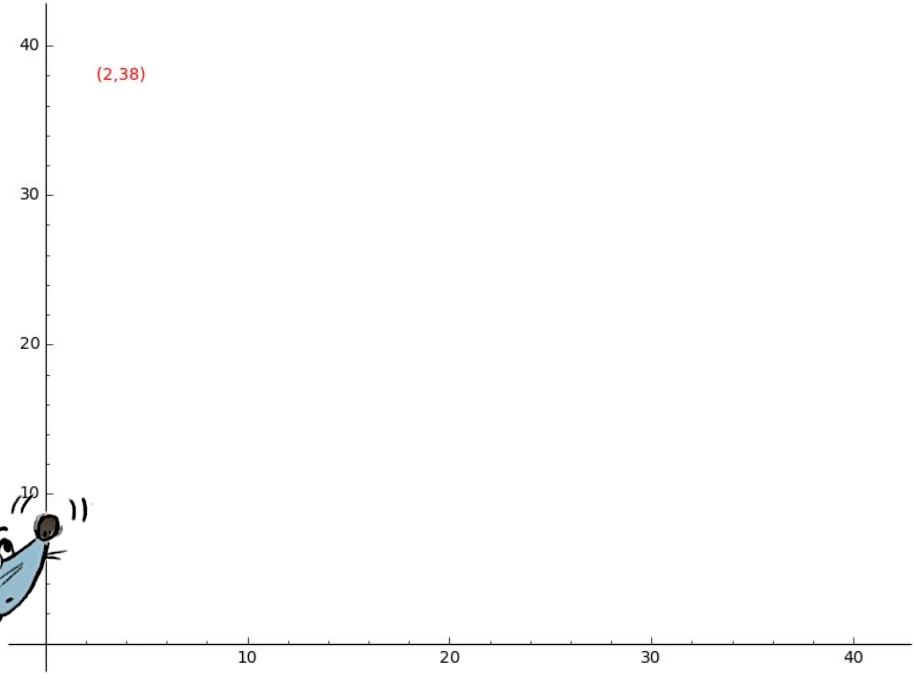
$31^{23} \bmod 55 = 36 = \text{“y”}$

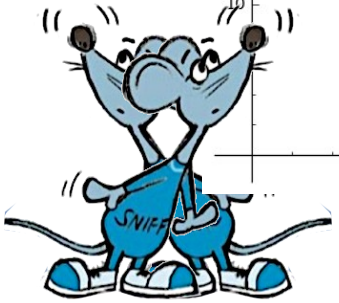
D(gellv) = Jimmy



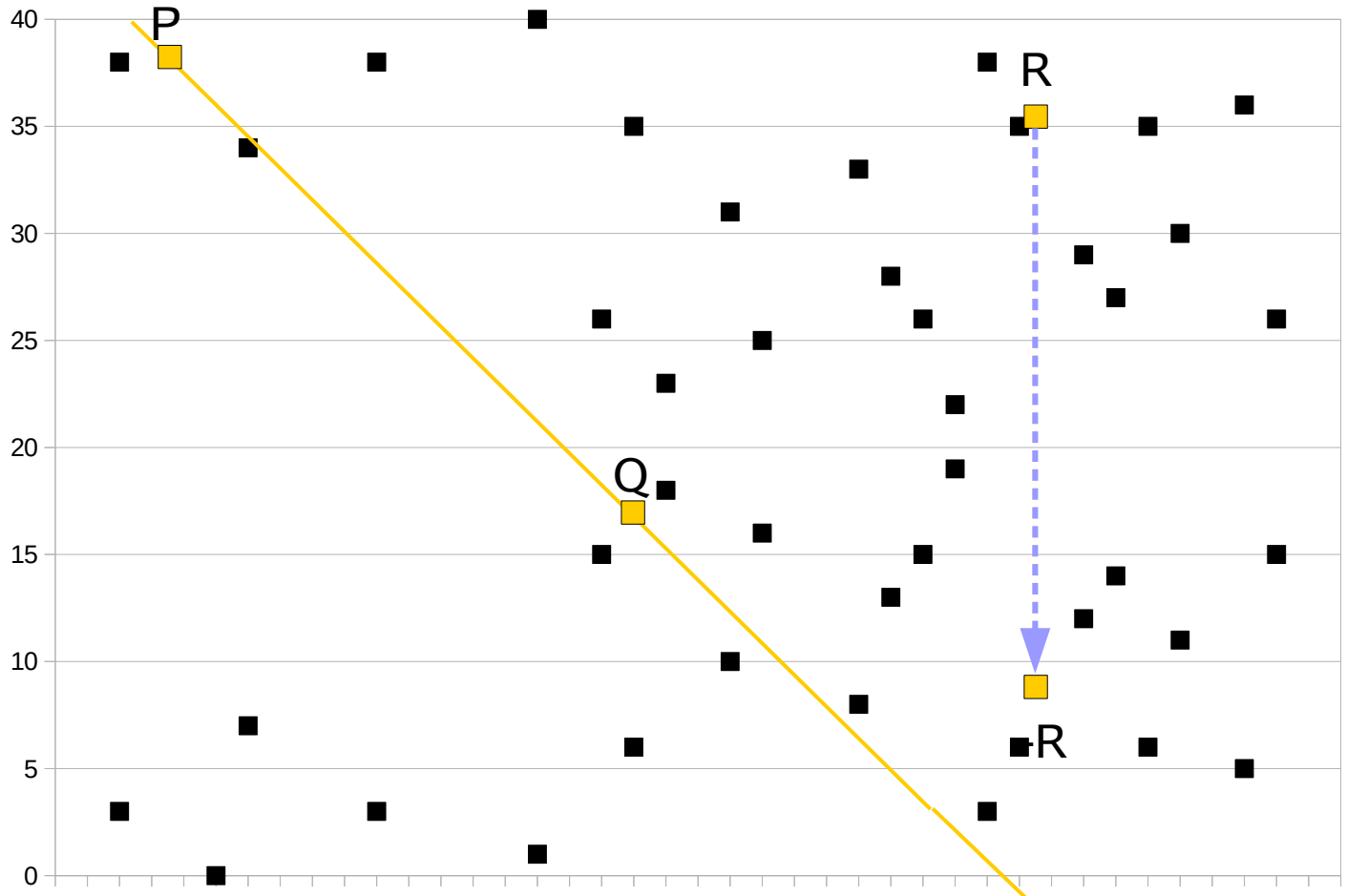
Elliptic Curve Cryptography







x	$y^2 \pmod{41} \equiv x^3 - x + 3 \pmod{41}$
2	3; 38
5	0
6	7; 34
10	3; 38
15	1; 40
17	15; 26
18	6; 35
...	…



$P \oplus Q \oplus R = 0$

$P \oplus Q = -R$

x $\quad y^2 \pmod{41} \equiv x^3 - x + 3 \pmod{41}$

2	3; 38
5	0
6	7; 34
10	3; 38
15	1; 40
17	15; 26
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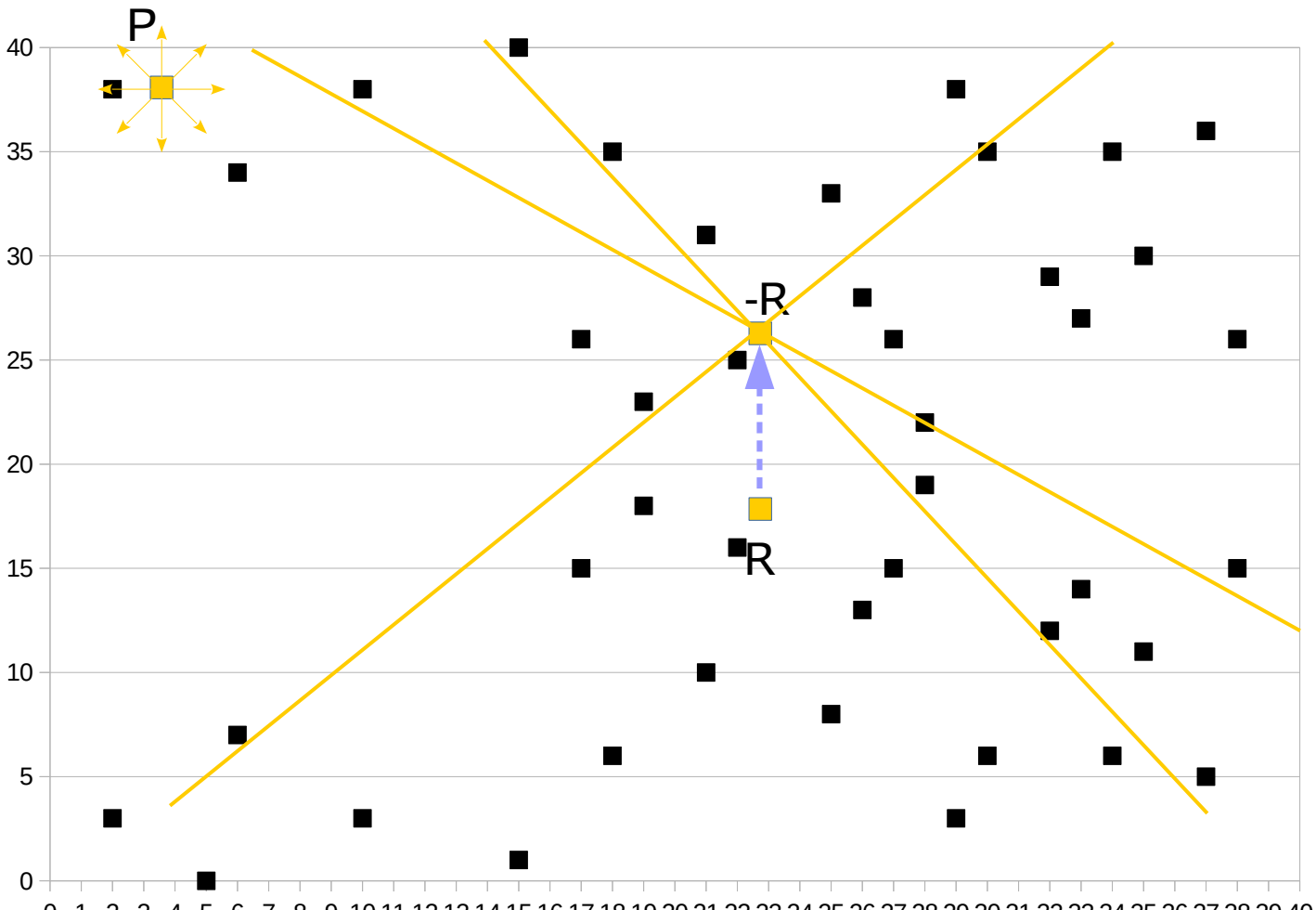
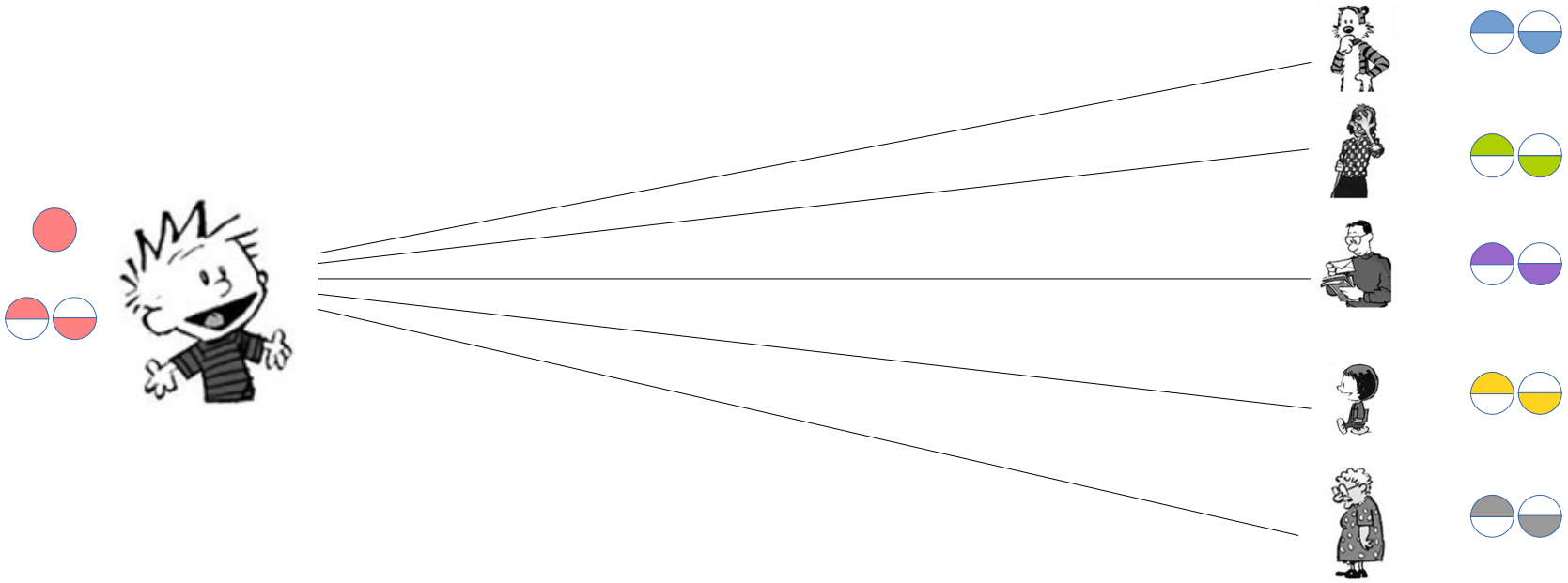
...	...



P + Q = -R

P + Q + R = 0

Asymmetric Key Cryptography



2*n = 2 * 6 = 12 unique keys

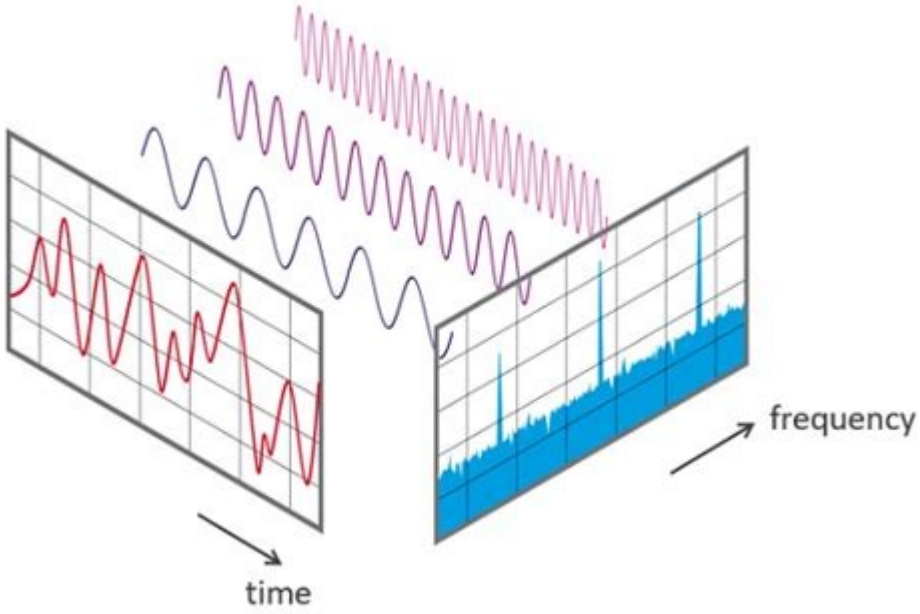
Quantum Computers

- Use qubits instead of classical bits
- Qubits can be in more than one state at the same time
- The state of a qubit is unknown until you observe it
- Qubits are fragile and interference can put them into an error state
- Error rates slow down the development of quantum computers

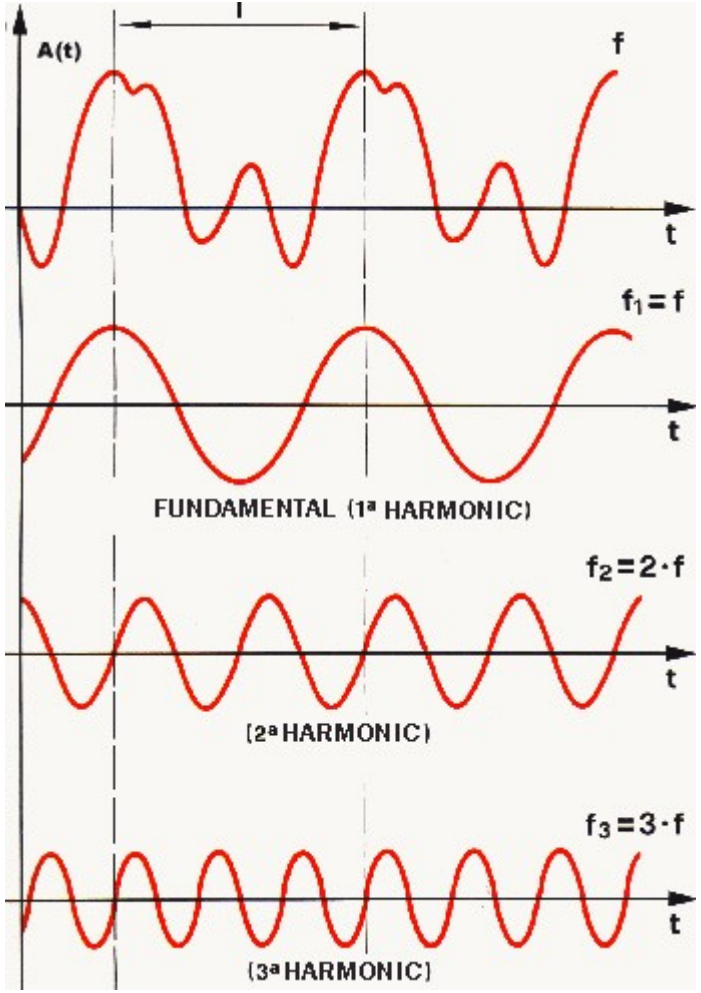
Shor’s Algorithm

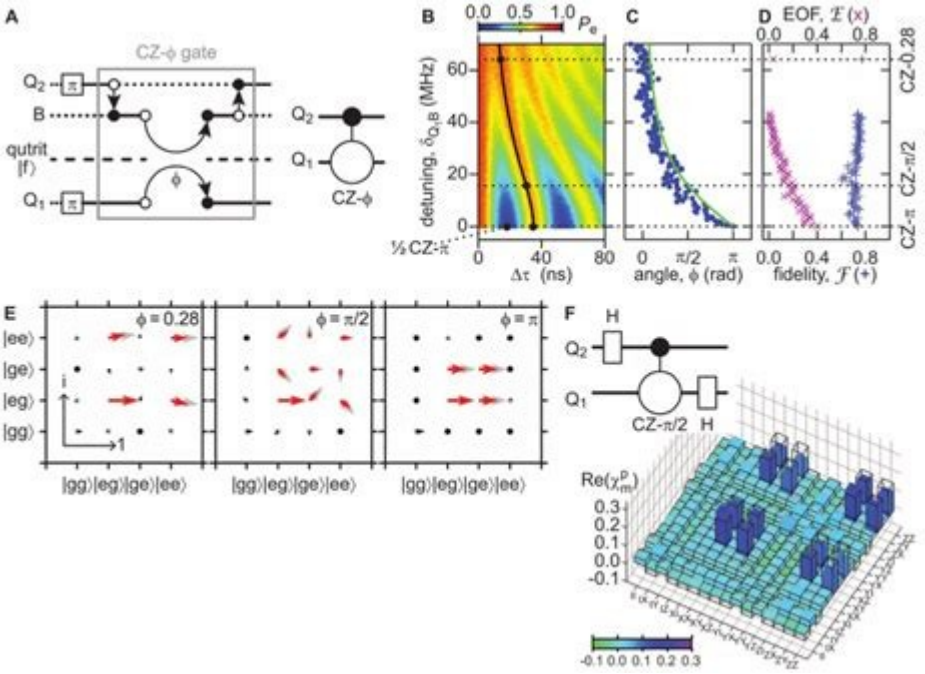
- Makes factoring large semiprimes obtainable
- Another algorithm for solving the discrete logarithm problem
- And yet another for the period finding problem
- With proper quantum computer, RSA, DH, ECC, ECDH all become obsolete

Fourier Transform



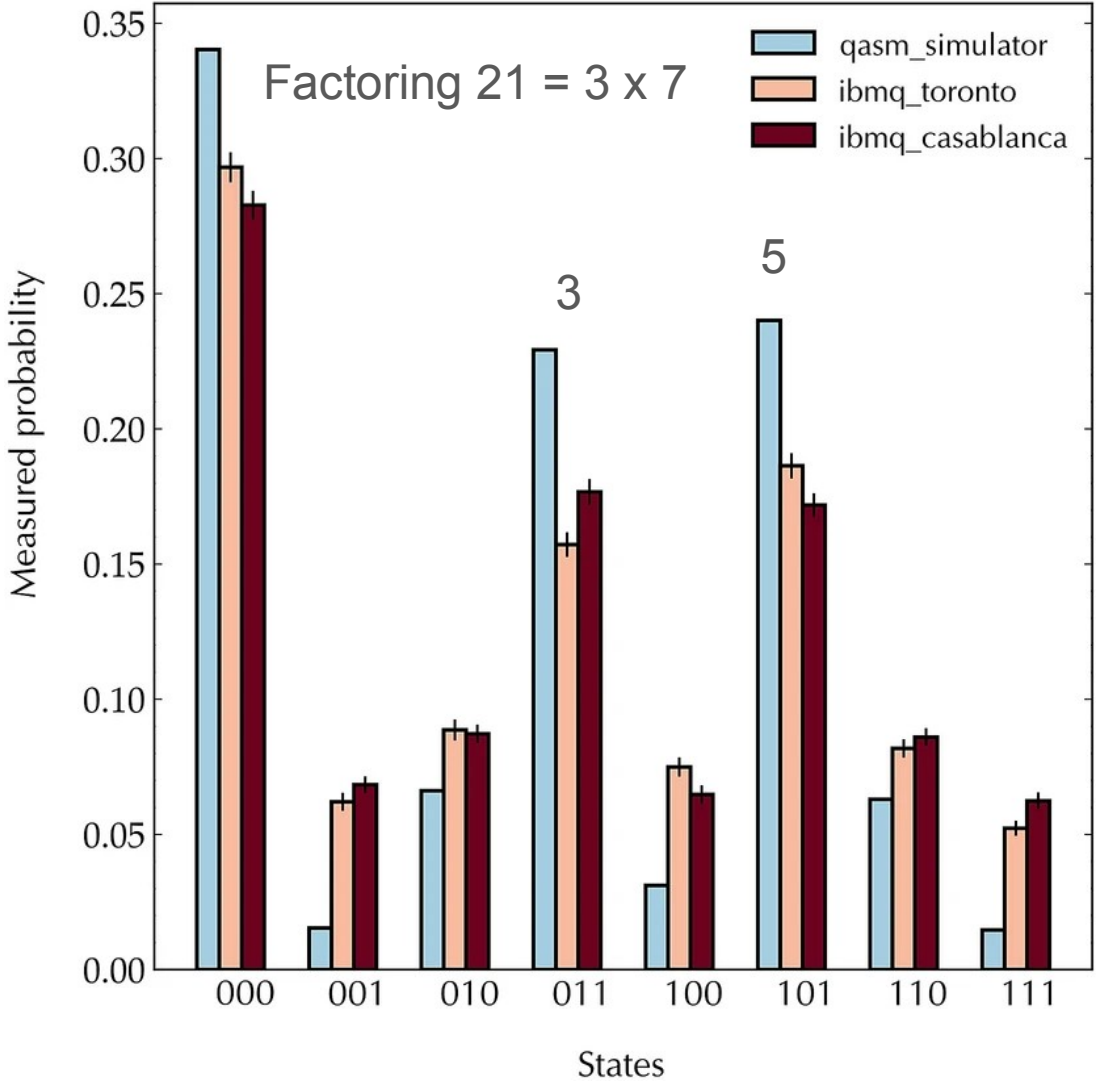
Fourier Transform




A
CZ-ϕ gate
Q2
B
qutrit
|f⟩
Q1
π
ϕ
CZ-ϕ
B
0.0 0.5 1.0 Pe
detuning, δQ,B (MHz)
60
40
20
0
½CZ-π
0 40 80
Δτ (ns)
C
0 π/2 π
angle, ϕ (rad)
D
EOF, ℰ(x)
0.0 0.4 0.8
fidelity, ℱ(+)
CZ-0.28
CZ-π/2
CZ-π
E
ϕ = 0.28
ϕ = π/2
ϕ = π
|ee⟩
|ge⟩
|eg⟩
|gg⟩
i
1
|gg⟩|eg⟩|ge⟩|ee⟩
F
H
Q2
Q1
CZ-π/2
H
Re(χmP)
0.3
0.2
0.1
0.0
-0.1
-0.1 0.0 0.1 0.2 0.3


HAW


SNIFF


Factoring 21 = 3 x 7
qasm_simulator
ibmq_toronto
ibmq_casablanca
Measured probability
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
3
5
000
001
010
011
100
101
110
111
States

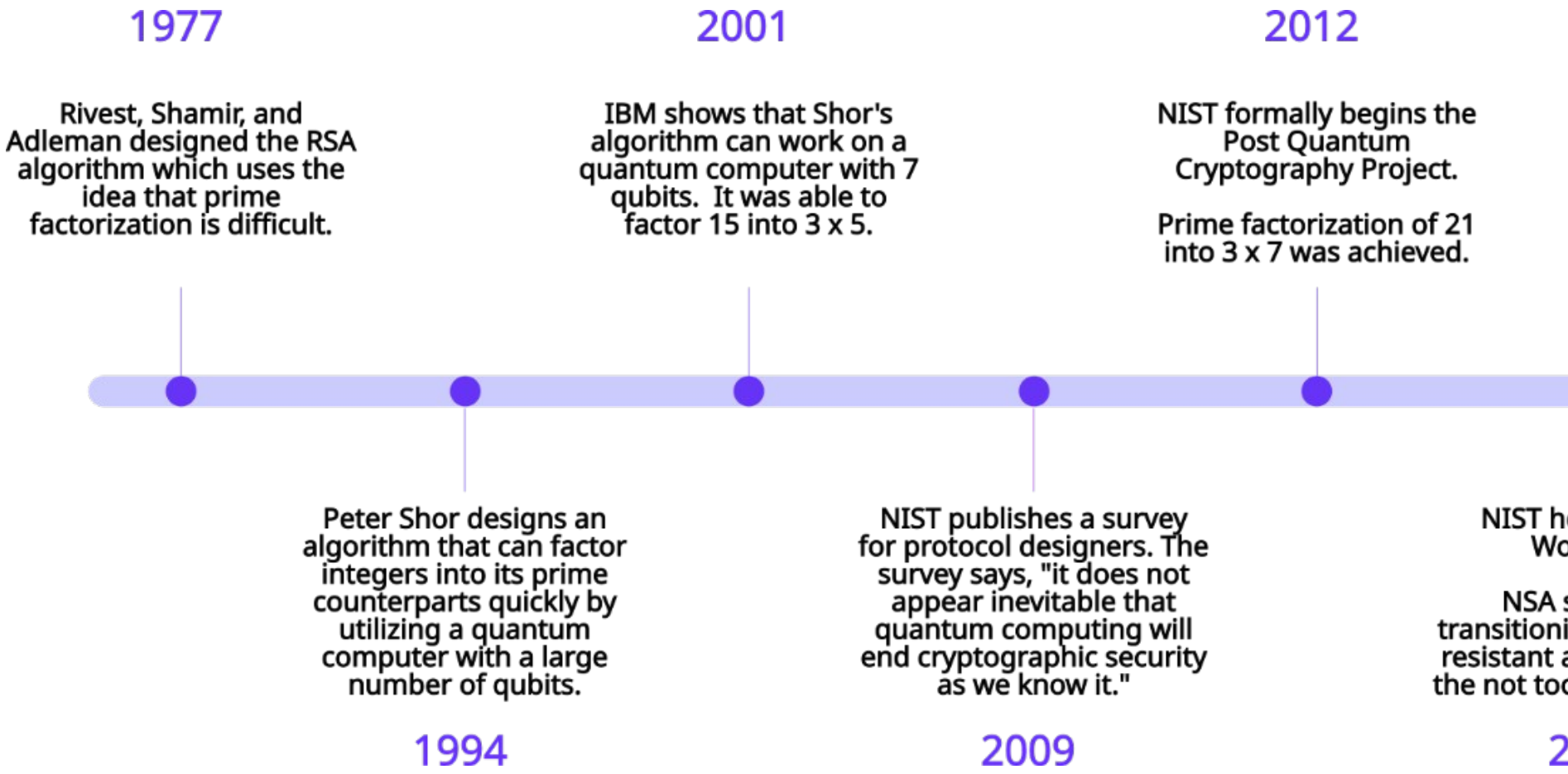
GEN NISQ

noisy intermediate-scale quantum era

GEN NISQ

noisy intermediate-scale quantum era

|not that worried, bra⟩


1977
Rivest, Shamir, and Adleman designed the RSA algorithm which uses the idea that prime factorization is difficult.
1994
Peter Shor designs an algorithm that can factor integers into its prime counterparts quickly by utilizing a quantum computer with a large number of qubits.
2001
IBM shows that Shor's algorithm can work on a quantum computer with 7 qubits. It was able to factor 15 into 3 x 5.
2009
NIST publishes a survey for protocol designers. The survey says, "it does not appear inevitable that quantum computing will end cryptographic security as we know it."
2012
NIST formally begins the Post Quantum Cryptography Project.
Prime factorization of 21 into 3 x 7 was achieved.

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Project.

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hieved.

2015

NIST holds 1st PQC Workshop.

NSA states that transitioning to quantum resistant algorithms is in the not too distant future.

2016

NIST publishes 1st report on PQC (8105). Deadlines for submissions of round one due in 2017.

2019

NIST holds 2nd PQC Workshop.

Attempt to factor 35 into primes fails due to accumulating errors.

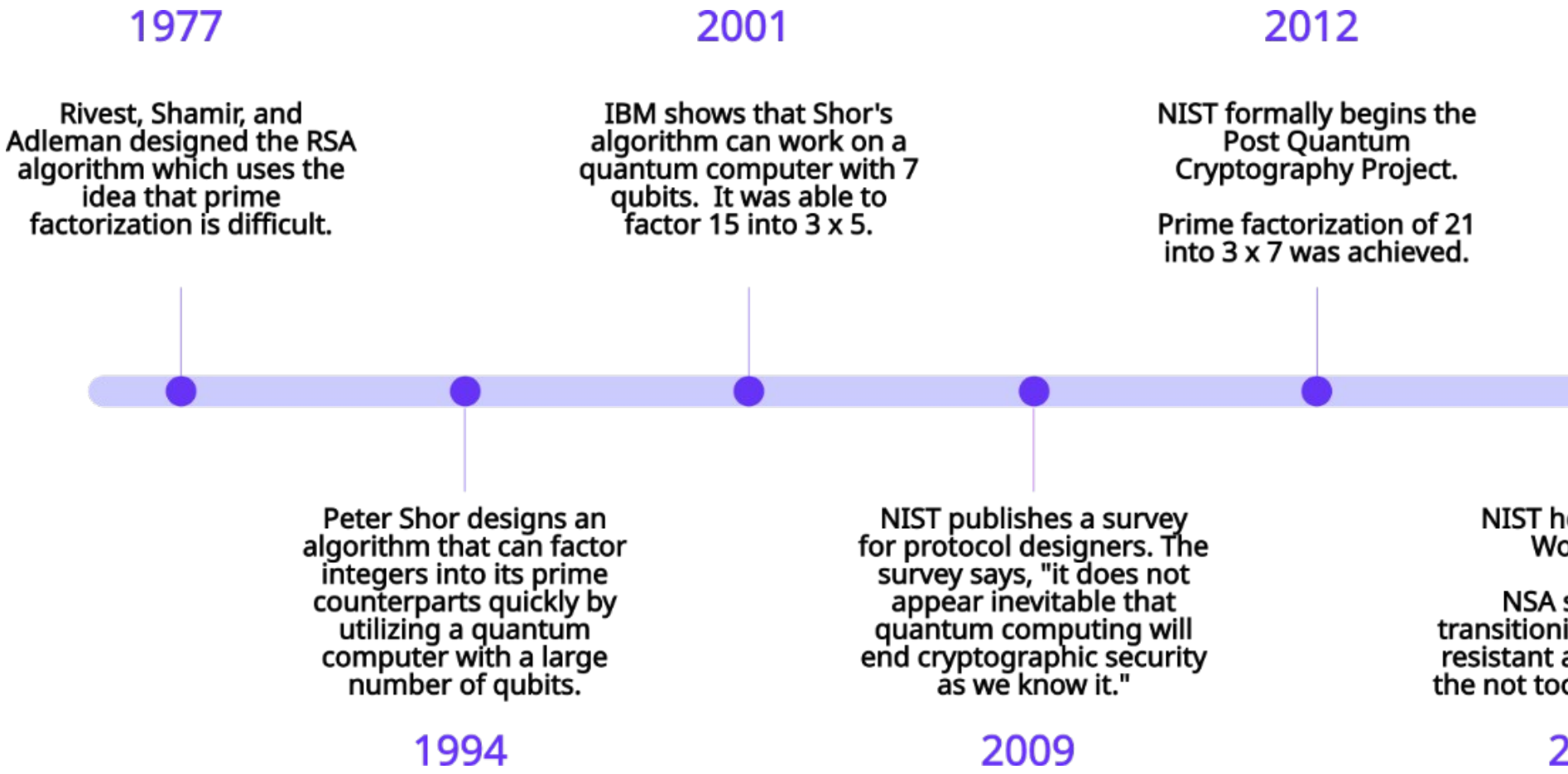
2021 & 2022

NIST holds 3rd & 4th PQC Workshop.

Draft standards made, algorithms selected for QSC (CRYSTALS-KYBER, CRYSTALS-DILITHIUM, FALCON, SPHINCS+).

2024

NIST announced that it will integrate the four selected post-quantum algorithms into U.S. encryption standards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Quantum Factored

4 bit semiprime (2001): 15

5 bit semiprime (2012): 21

6 bit semiprime (2019 - failed): 35

Need to factor

1024 bit semiprime:

14858031842529041742675223662020065615490358969220662
89933239251279096441074379066840500275518447762785965
12160601382625659982180758999544221868254722043619979
84526745656869867322663775380667065617182042243040564
49791211661181323805868000257522596407301217381568222
96246476504443847811940638639921190244907229

Need to factor

2048 bit semiprime:

23042155144807033264822777505847352979234760665383921887127664352
78228085219412095936558643453832808918618527312570608206987897806
77826686707683634384826161371591122821396878931674234574664588025
31248068491920362991080654721527620276216893955001892785769536572
67267439816306389312211303562793907011141430028528465970927469108
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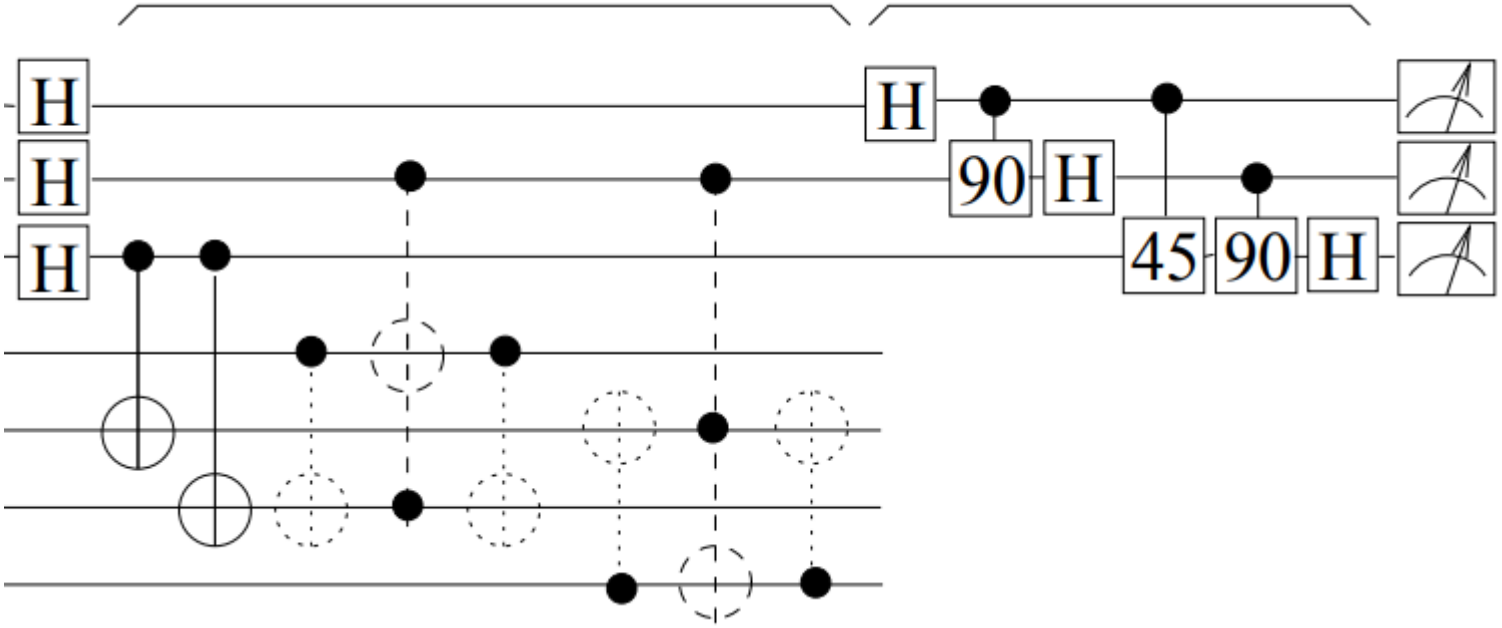
59125201782358647860679882638386416987498248726270464804391684357
18938652132696815444783098028151462344977286590749544794608585623
58276343440681884962113194327925057965815020957943883829290034086
29452106790235491702341492875849

Need to factor

4096 bit semiprime:

895042969348578296981915910336163678732453124759533145586557604952895760317776316569158676150827486124282107892547967130332914027774243839644745256753400595926775963454953677271868790785113833576640691167921680046506876548102235826951106601104321424115479228484934247680630146283879498848910449797060157700850496337813043477561293777835401086614295601519110057733873752161156353028368807727894927096506522360815072003186182464302107329240801651864447332432227480806121176546660163477961207908730137818046855075860397970872099230128151889729620508160890782546593607782476115722199666190983162590520741299726377775088716806070106496493062874472415479023496763767874917569948669544950361493264214164541577312583731983304075229287865529835971053244670543287945198597007230421194138598762200939985241659753438228960525439886371016023854489945527427016801283327238740264623041454543856910545747681154748200516832481353745896101528766394364192199682267695484131145194250945616529523978521590091466213527524706661778437750247039074736641799486281849406242236762484545429225759181886778743331440696334172440423765256156865851502929465513715146197453647468878018363628603489424424030802769700952150094244596873055650438391281230331589881854277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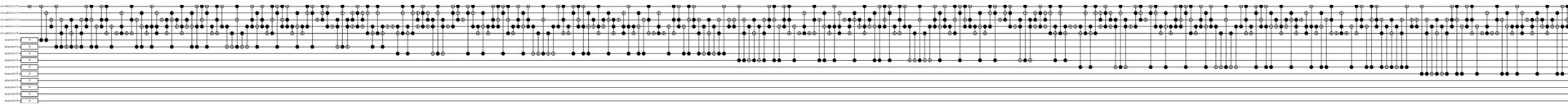
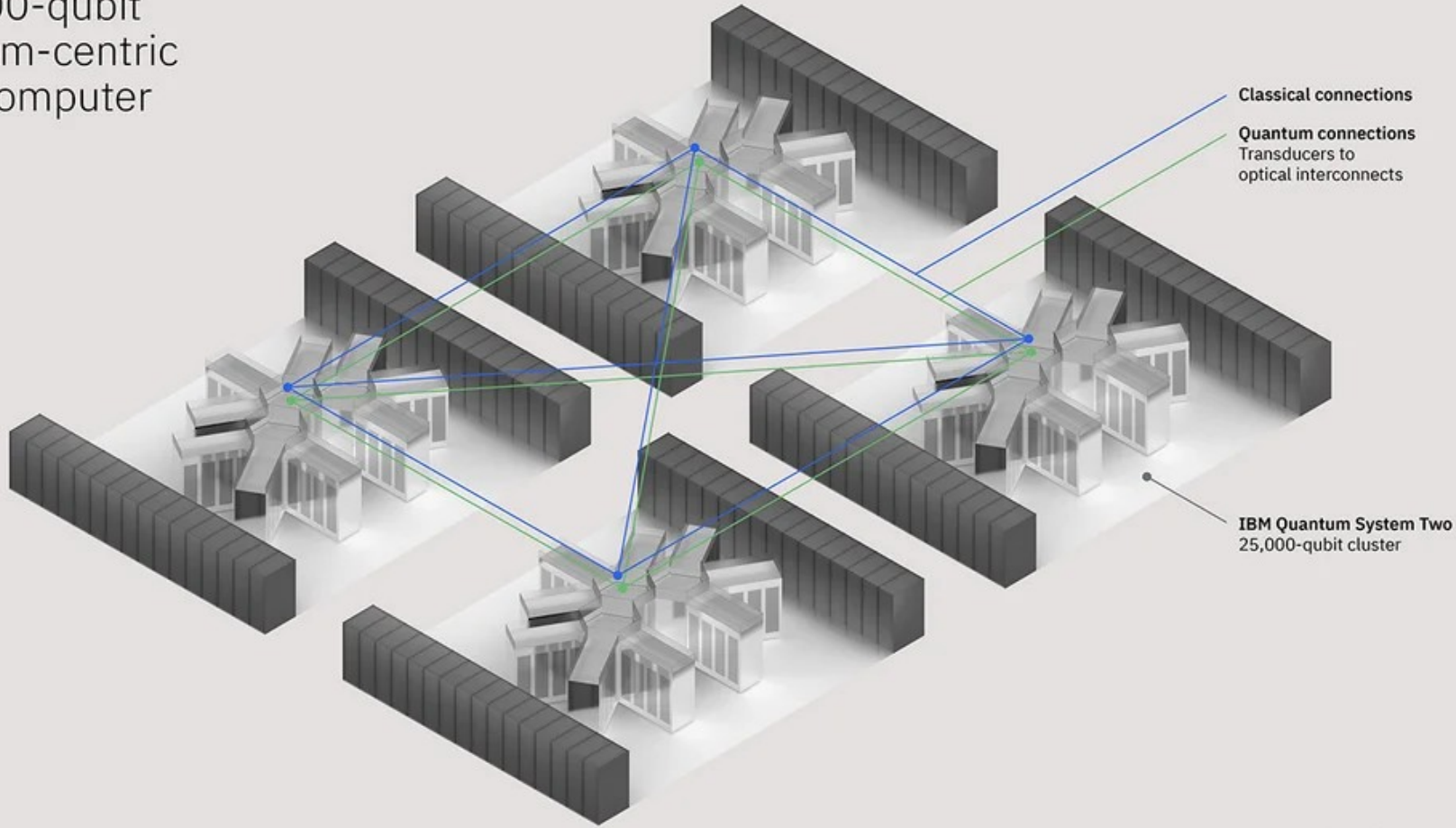


100,000-qubit
quantum-centric
supercomputer
—
2033



IBM **Quantum**

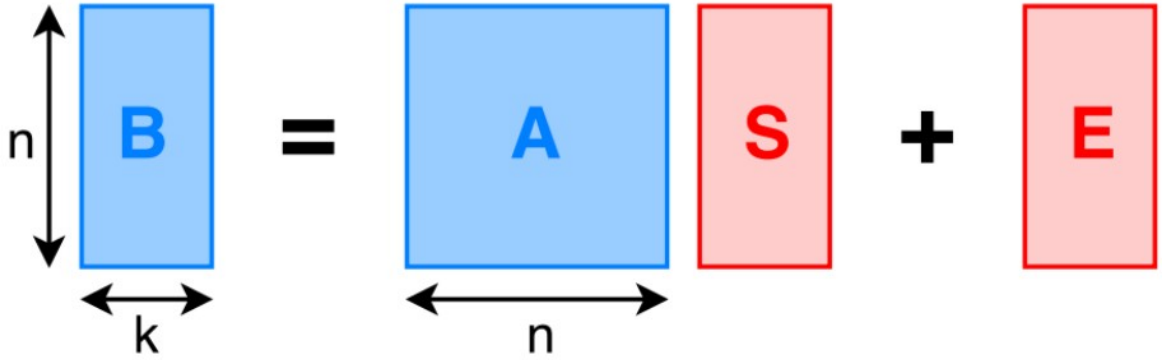
Post-Quantum Cryptography (PQC) - where are we?

2022 NIST approves PQC encryption and signature algorithms

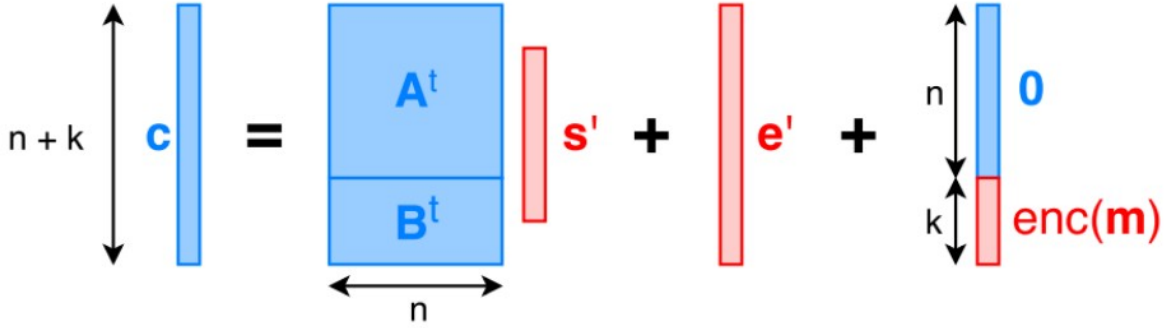
- CRYSTALS-Kyber (general encryption) - ML-KEM
- CRYSTALS-Dilithium (signature) - ML-DSA
- FALCON (signatures for smaller applications) - FN-DSA
- SPHINCS+ (based on a different mathematical model) - SLH-DSA

Public parameter $\mathbf{A} \leftarrow \mathcal{U}(\mathbb{Z}_q^{n \times n})$

KeyGen()



Encrypt$_{\mathbf{b}}(m \in \{0,1\})$



Post-Quantum Cryptography (PQC) - where are we?

- X25519MLKEM768 (formerly X25519Kyber768Draft00) readily available to test
  - Google Chrome
  - Firefox
  - BoringSSL
  - Nginx
- IAS - https://pqc.ias.edu (with presentation slides!)
- Cloudflare Research - https://pq.cloudflareresearch.com/
- Signal - https://signal.org/blog/pqxdh/
- Apple iMessage - https://security.apple.com/blog/imessage-pq3/

Experiments

Chrome | chrome://flags

kyber

Reset all

Experiments

119.0.6045.199

Available | Unavailable

TLS 1.3 hybridized Kyber support

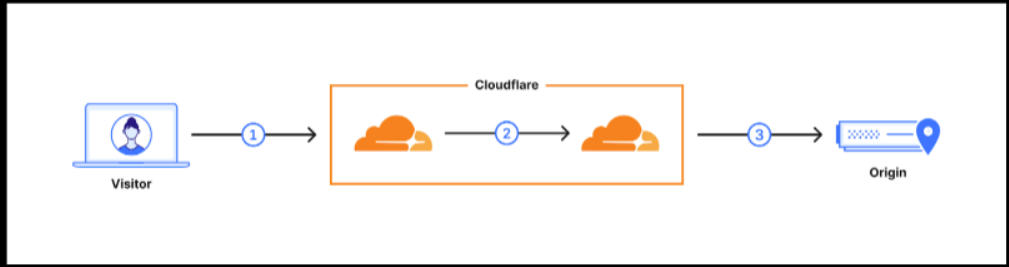
This option enables a combination of X25519 and Kyber in TLS 1.3. – Mac, Windows, Linux, ChromeOS, Android, Fuchsia, Lacros

#enable-tls13-kyber

Enabled

Experiments | Post-Quantum Key Agree | pq.cloudflareresearch.com

Cloudflare Research: Post-Quantum Key Agreement



On essentially all domains served (1) through Cloudflare, including this one, we have enabled hybrid post-quantum key agreement. We are also rolling out support for post-quantum key agreement for connection from Cloudflare to origins (3).

You are using *X25519Kyber768Draft00* which is **post-quantum secure**.

Deployed key agreements

Available with TLSv1.3 including HTTP/3 (QUIC)

Key agreement	TLS identifier
X25519Kyber768Draft00	`0x6399` (recommended) and `0xfe31` (obsolete)
X25519Kyber512Draft00	`0xfe30`

X25519Kyber*{x}*Draft00 is a hybrid of X25519 and Kyber*{x}*Draft00 (in that order).

Software support

- **Chrome** 116+ if you turn on *TLS 1.3 hybridized Kyber support* (`enable-tls13-kyber`) in `chrome://flags`.

DevTools - security.stackexchange.com/questions/120777/chrome-50-where-can-i-see-the-negotiated...

Elements | Console | Sources | Network | Performance | Memory | Application | Security | 10

Overview

Main origin

Reload to view details

Security overview

This page is secure (valid HTTPS).

Certificate - valid and trusted

The connection to this site is using a valid, trusted server certificate issued by E1.

View certificate

Connection - secure connection settings

The connection to this site is encrypted and authenticated using TLS 1.3, X25519Kyber768Draft00, and AES_128_GCM.

Resources - all served securely

All resources on this page are served securely.

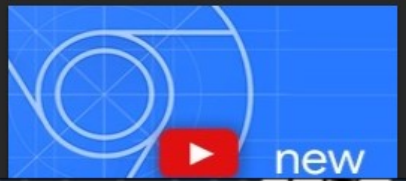
Console | What's New

Highlights from the Chrome 119 update

Improved @property section in Elements > Styles

You can now edit the @property rule in Elements > Styles.

Updated list of devices



What do we need to do?

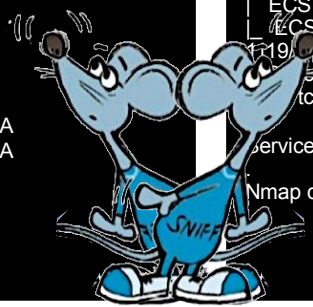
1. Don’t panic.
2. Educate yourself and your company on the risks.
3. Understand your environment.
    a. Where do you use encryption?
    b. What type of encryption do you use?
    c. Can you update? Are your vendors working on implementing PQC?
    d. Realize that you should be auditing your encryption usage anyway.

```
[1]ep:~$ nmap -sV --script ssl-enum-ciphers --script ssl-cert www.example.com
Starting Nmap 7.93 ( https://nmap.org ) at 2023-12-12 20:54 EST
Nmap scan report for www.example.com (93.184.216.34)
Host is up (0.0055s latency).
Other addresses for www.example.com (not scanned):
2606:2800:220:1:248:1893:25c8:1946
Not shown: 995 filtered tcp ports (no-response)
PORT     STATE  SERVICE   VERSION
80/tcp   open   http      Edgecast CDN httpd (nyb/1DCD)
|_http-server-header: ECS (nyb/1DCD)
443/tcp  open   ssl/http  Edgecast CDN httpd (nyb/1DCD)
| ssl-enum-ciphers:
|   TLSv1.0:
|     ciphers:
|     compressors:
|       NULL
|     cipher preference: server
|   TLSv1.1:
|     ciphers:
|       TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA (secp256r1) - A
|       TLS_DHE_RSA_WITH_AES_128_CBC_SHA (dh 2048) - A
|       TLS_DHE_RSA_WITH_AES_256_CBC_SHA (dh 2048) - A
|       TLS_DHE_RSA_WITH_CAMELLIA_256_CBC_SHA (dh 2048) - A
|       TLS_DHE_RSA_WITH_CAMELLIA_128_CBC_SHA (dh 2048) - A
|       TLS_RSA_WITH_AES_256_CBC_SHA (rsa 2048) - A
|       TLS_RSA_WITH_CAMELLIA_256_CBC_SHA (rsa 2048) - A
|       TLS_DHE_RSA_WITH_SEED_CBC_SHA (dh 2048) - A
|     compressors:
|       NULL
|     cipher preference: server
|   TLSv1.2:
|     ciphers:
|       TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256 (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384 (secp256r1) - A
|       TLS_DHE_RSA_WITH_AES_128_GCM_SHA256 (dh 2048) - A
|       TLS_DHE_RSA_WITH_AES_256_GCM_SHA384 (dh 2048) - A
|       TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA256 (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA384 (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA (secp256r1) - A
|     compressors:
|       NULL
|     cipher preference: server

|   TLSv1.3:
|     ciphers:
|       TLS_AKE_WITH_AES_256_GCM_SHA384 (secp256r1) - A
|       TLS_AKE_WITH_CHACHA20_POLY1305_SHA256 (secp256r1) - A
|       TLS_AKE_WITH_AES_128_GCM_SHA256 (secp256r1) - A
|     cipher preference: server
|_  least strength: A
| ssl-cert: Subject: commonName=www.example.org/organizationName=Internet\xC2\
xA0Corporation\xC2\xA0for\xC2\xA0Assigned\xC2\xA0Names\xC2\xA0and\xC2\
xA0Numbers/stateOrProvinceName=California/countryName=US
| Subject Alternative Name: DNS:www.example.org, DNS:example.net, DNS:example.edu,
DNS:example.com, DNS:example.org, DNS:www.example.com, DNS:www.example.edu,
DNS:www.example.net
| Issuer: commonName=DigiCert TLS RSA SHA256 2020 CA1/organizationName=DigiCert
Inc/countryName=US
| Public Key type: rsa
| Public Key bits: 2048
| Signature Algorithm: sha256WithRSAEncryption
| Not valid before: 2023-01-13T00:00:00
| Not valid after:  2024-02-13T23:59:59
| MD5:   749bbbeb4a6cb23c205c9850b35bed6a
|_SHA-1: f2aad73d32683b716d2a7d61b51c6d5764ab3899
| http-server-header:
|   ECS (nyb/1D2E)
|_  ECS (nyb/1DCD)
1719/tcp closed bnetgame
5060/tcp open   h323q931?
5061/tcp closed rtmp

Service detection performed. Please report any incorrect results at https://nmap.org/submit/

Nmap done: 1 IP address (1 host up) scanned in 189.80 seconds
```



What do we need to do?

1. Plan
    a. What can you upgrade?
    b. What can’t you upgrade?
    c. Risk Analysis
2. Execute your Plan
3. Automation
    a. ACME - Automatic Certificate Management Environment
    b. SCEP - Simple Certificate Enrollment Protocol
    c. REST/API - Check with your certificate provider, InCommon supports this

CYBER RISK

DARKREADING TECHNOLOGY

News, news analysis, and commentary on the latest trends in cybersecurity technology.

Google Proposes Reducing TLS Cert Life Span to 90 Days

Organizations will likely have until the end of 2024 to gain visibility and control over their keys and certificates.

Dark Reading Staff, Dark Reading

March 14, 2023

2 Min Read

Latest Articles in DR Technology

BLOG POST | OCT 11, 2024

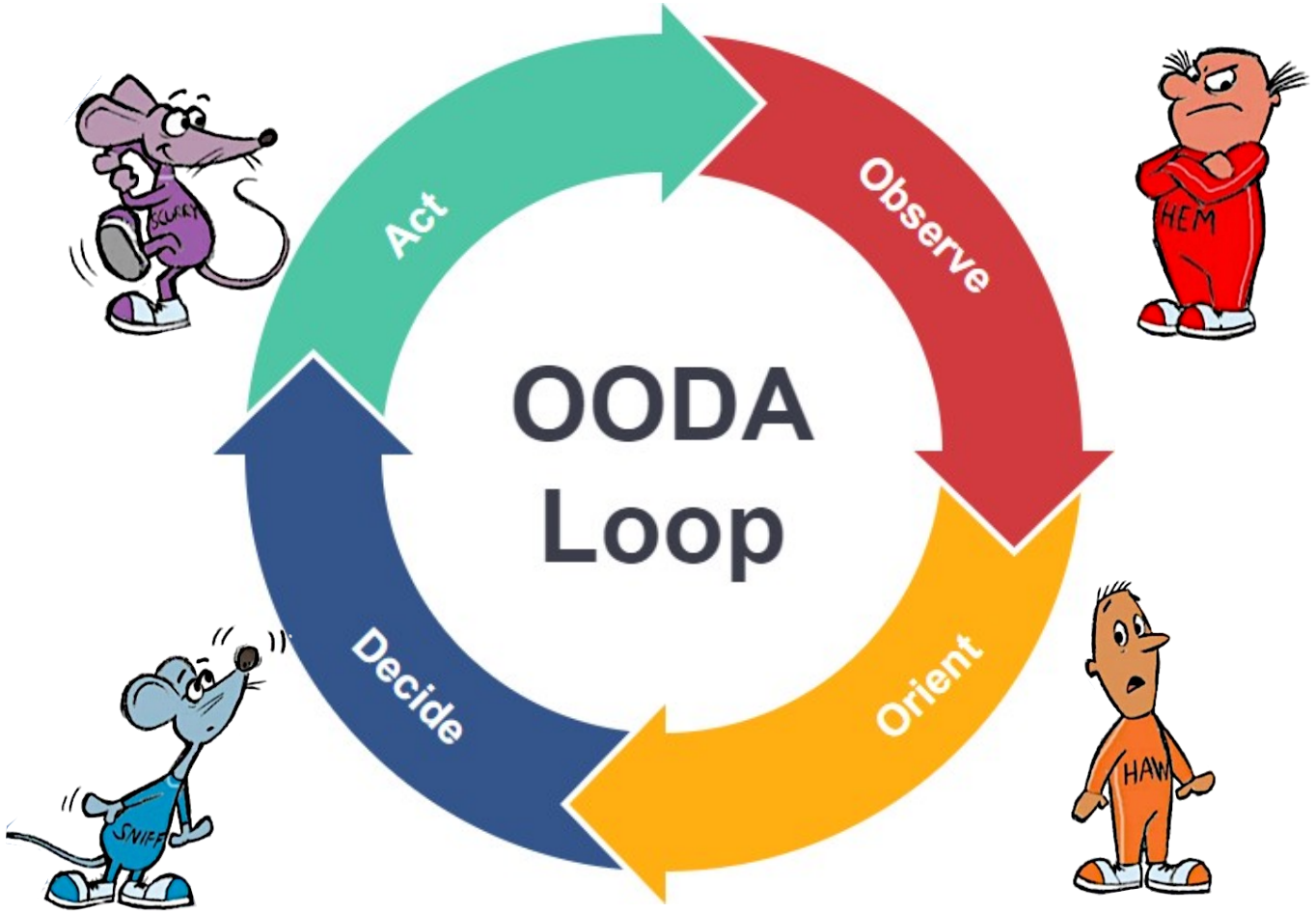
Apple Releases Draft Ballot to Shorten Certificate Lifespan to 45 Days

Share this Subscribe

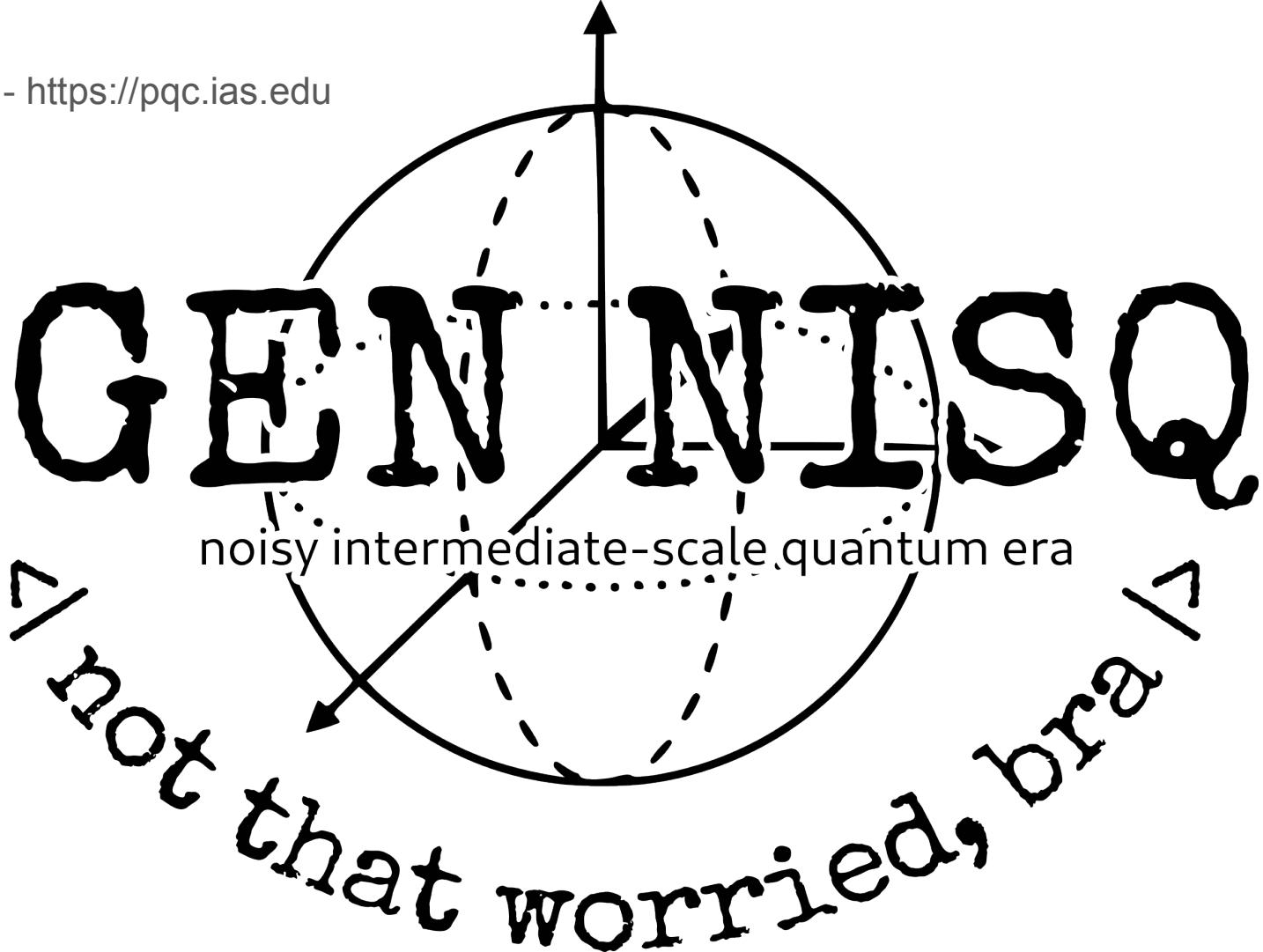
Earlier this week, on October 9, during the second day of the fall CA/Browser Forum Face-to-Face meeting, Apple revealed that it had published a draft ballot for commentary to GitHub. This proposal, which is sponsored by Sectigo, offers to incrementally phase maximum term for public SSL/TLS certificates down to 45 days between now and 2027. The draft also phases down the DCV reuse period over time, until it reaches 10 days in 2027.

Module-Lattice-based Key-Encapsulation Mechanism FIPS-203

13. Qualifications. In applications, the security guarantees of a KEM only hold under certain conditions (see NIST SP 800-227 [1]). One such condition is the secrecy of several values, including the randomness used by the two parties, the decapsulation key, and the shared secret key itself. Users shall, therefore, guard against the disclosure of these values. While it is the intent of this standard to specify general requirements for implementing ML-KEM algorithms, **conformance to this standard does not ensure that a particular implementation is secure**. It is the responsibility of the implementer to ensure that any module that implements a key establishment capability is designed and built in a secure manner. Similarly, the use of a product containing an implementation that conforms to this standard does not guarantee security of the overall system in which the product is used. The responsible authority in each agency or department shall ensure that an overall implementation provides an acceptable level of security. NIST will continue to follow developments in the analysis of the ML-KEM algorithm. As with its other cryptographic algorithm standards, **NIST will formally reevaluate this standard every five years**. Both this standard and possible threats that reduce the security provided through the use of this standard will undergo review by NIST as appropriate, taking into account newly available analysis and technology. In addition, the awareness of **any breakthrough in technology or any mathematical weakness of the algorithm will cause NIST to reevaluate** this standard and provide necessary revisions.


Act
Observe
Orient
Decide
OODA
Loop
SCURRY
HEM
HAW
SNIFF

Slides - https://pqc.ias.edu



Who Moved my Rock?

Post-Quantum Cryptography and its Impact on Higher Education

We live in an age of misinformation, fear, uncertainty, and doubt. I put together this talk to discuss where we are with Post-Quantum Cryptography and whether it is time to panic or not.

Who am I?

Brian Epstein (he/him) - bepstein@ias.edu

Institute for Advanced Study - ias.edu/security

IT Manager, Network and Security
Chief Information Security Officer

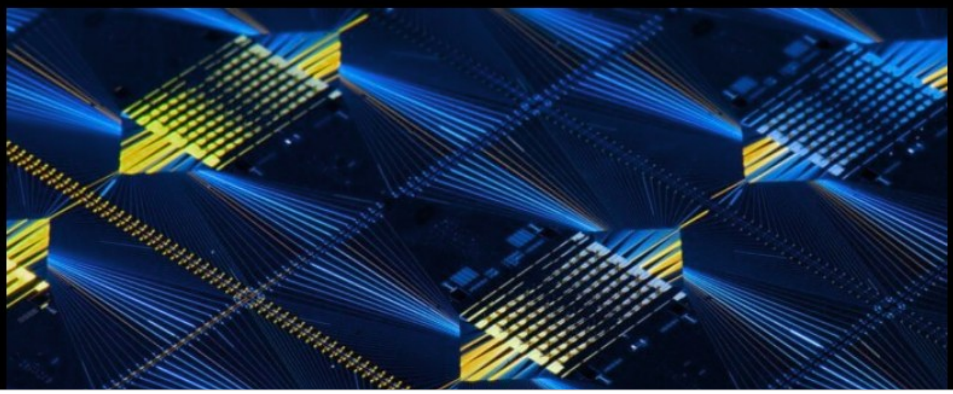
Mastodon: infosec.exchange/@ep

My name is Brian Epstein, my pronouns are he him. I’m not a cryptographer, but I have been a practitioner of cryptography for over two decades in my career in IT. I currently work at the Institute for Advanced Study in Princeton, NJ and serve the role as IT Manager for Network and Security and the Chief Information Security Officer. The Institute for Advanced Study promotes the disinterested pursuit of knowledge unburdened from distraction for our scholars.

I always try to tie in the main tenets of Information Security into my talks.
Today we'll be focusing mainly on Confidentiality and Integrity.

Quantum Computers Could Crack Encryption Sooner Than Expected With New Algorithm

By **Edd Gent** › October 2, 2023



FEATURED

Mice Just Passed the Mirror Test. Here's What That Says About Our Sense of Self
December 7, 2023

Load more ›

It's hard to determine what is truth and what is fiction in today's quantum news.

INTERESTING ENGINEERING

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China's new quantum code-breaking algorithm raises concerns in the US

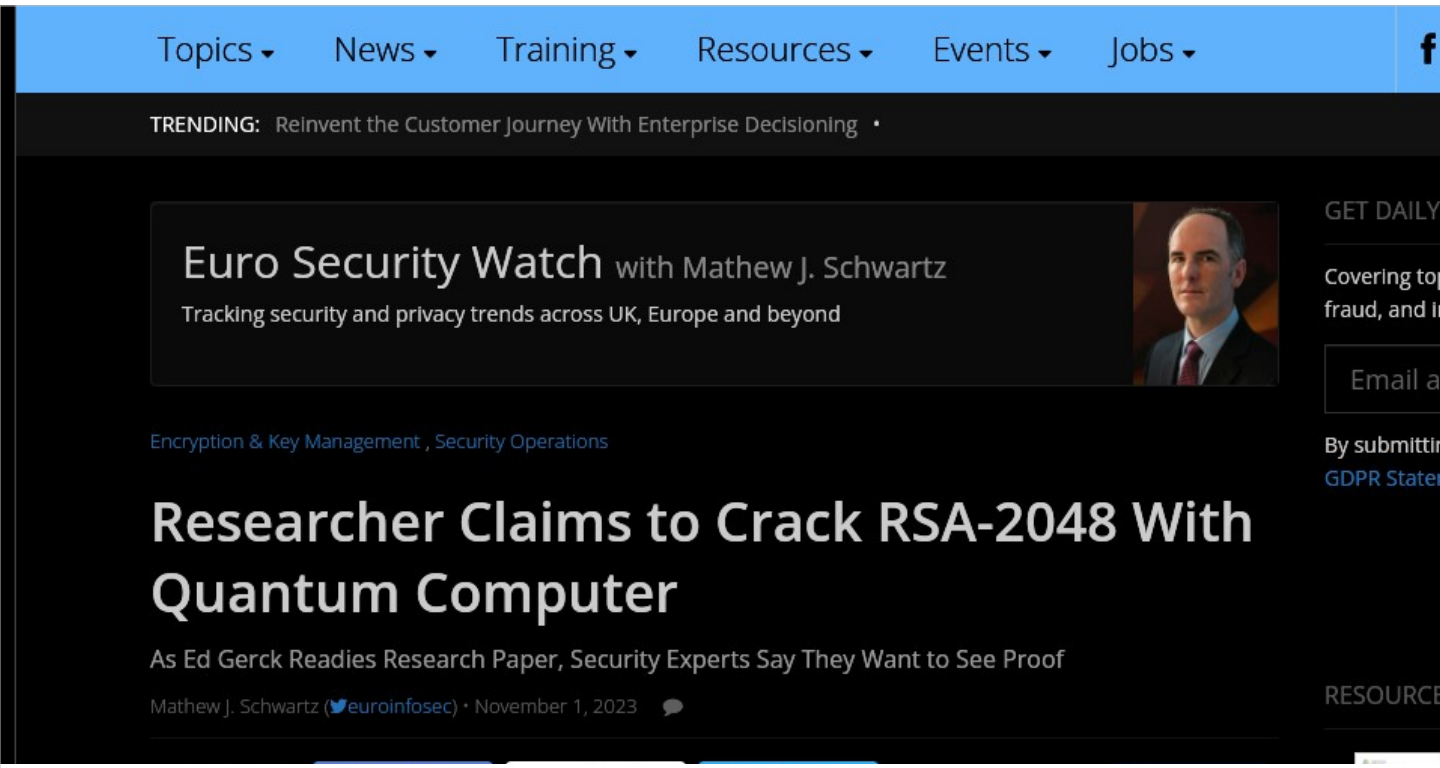
The new algorithm could render mainstream encryption powerless within years.

Baba Tamim

Published: Jan 12, 2023 06:56 AM EST

INNOVATION

Headlines like these come out on a daily basis.



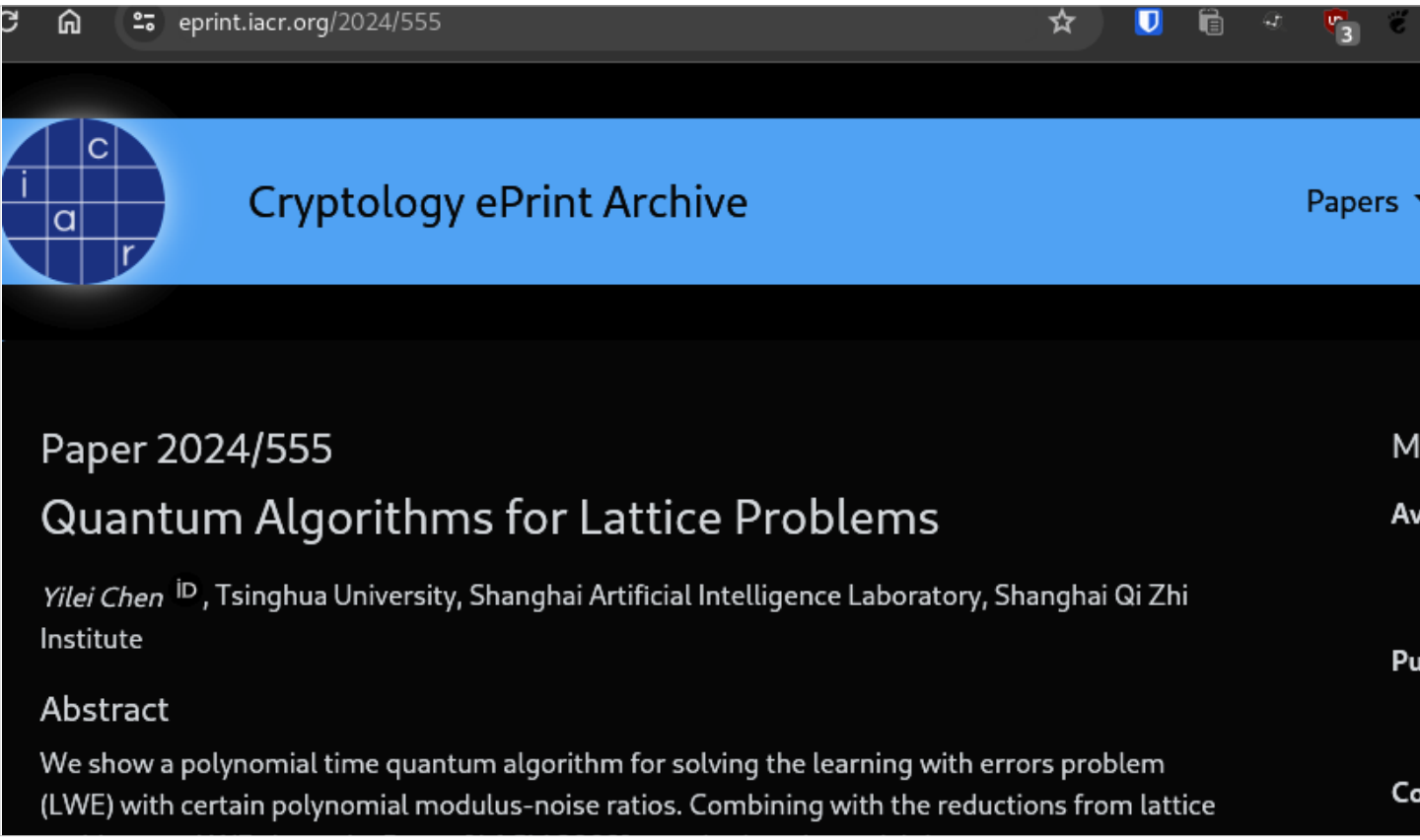
Sometimes they point to stories that are difficult to believe.

And sometimes you just see articles that are plain fake.

Guest Post: Harvest Now, Decrypt Later? The Truth Behind This Common Quantum Theory

Insights Jeffrey Duran • February 7, 2023

What should we believe and what should we be skeptical about?



And this other one caused a bit of a panic soon after. It claimed to be able to break the new Quantum Safe Cryptography we will discuss in this talk. A week later, the author revealed that a “bug” was found in the paper and removed the claim.

Chinese Researchers Tap Quantum to Break Encryption

But the time when quantum computers pose a tangible threat to modern encryption is likely still several years away.

Jai Vijayan, Contributing Writer
October 16, 2024

4 Min Read

SOURCE: FUNTAP VIA SHUTTERSTOCK

Researchers at China's Shanghai University have demonstrated how quantum mechanics could pose a realistic threat to current encryption schemes even before full-fledged quantum computers become available.

The researchers' paper describes how they developed a working RSA public key cryptography attack using D-Wave's Advantage quantum computer. Specifically, the researchers used the computer to successfully factor a 50-bit integer into its prime factors, thereby giving them a way to derive private keys for decryption.

Editor's Choice

OWASP Beefs Up GenAI Security Guidance Amid Growing Deepfakes

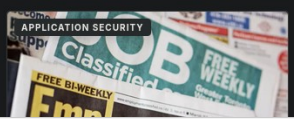
by Robert Lemos, Contributing Writer

NOV 4, 2024 5 MIN READ

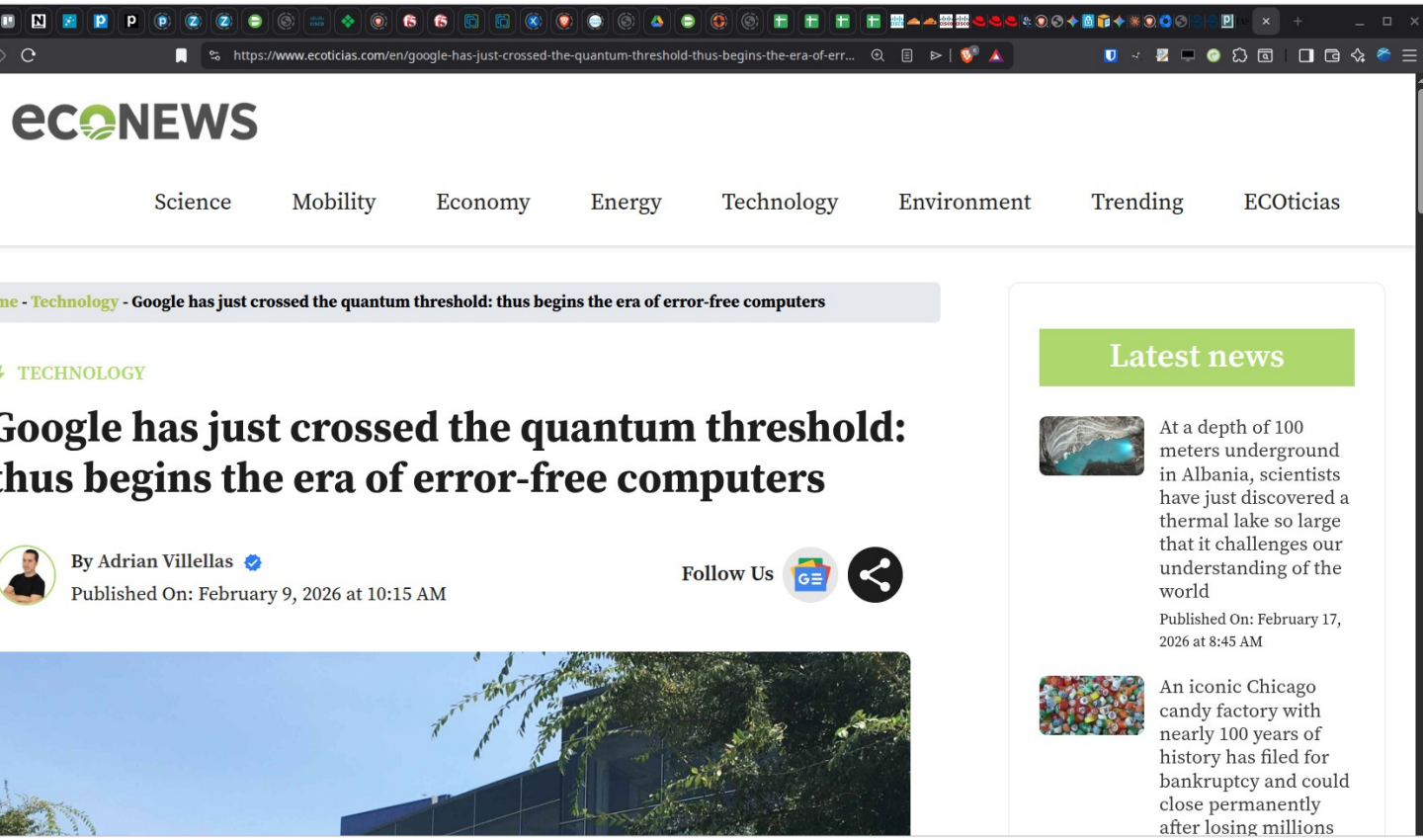
How to Win at Cyber by Influencing People

by Gregory R. Simpson

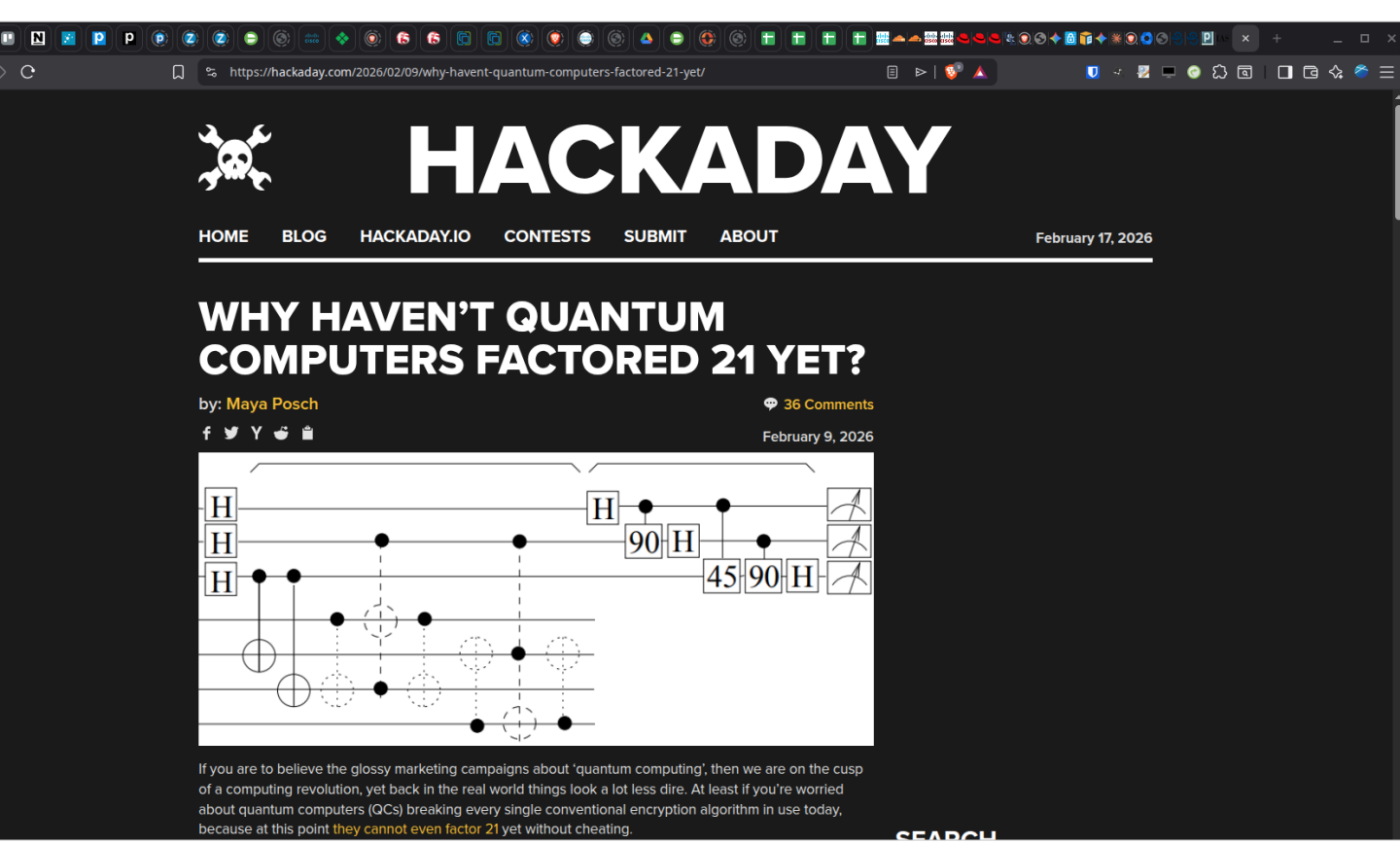
NOV 5, 2024 5 MIN READ



October 2024, this article came out talking about factoring a 50bit number



In February 2026, an article came out about how Google crossed the quantum threshold when it comes to error-free quantum computers.



And on the same day, and article came out about how terrible quantum computers are because they cannot solve the prime factorization of 21 due to the number of errors that quantum computers have.

So what should we be doing to protect ourselves and our institutions?

Characters

Hem - angry, impatient, unwilling to move

Haw - scared stiff, but thinks

Sniff - always using their tools

Scurry - always on the move to discover new things

For this talk we'll follow a cast of characters and their adventures through history. We borrow them from the popular book by Spencer Johnson, "Who Moved My Cheese".

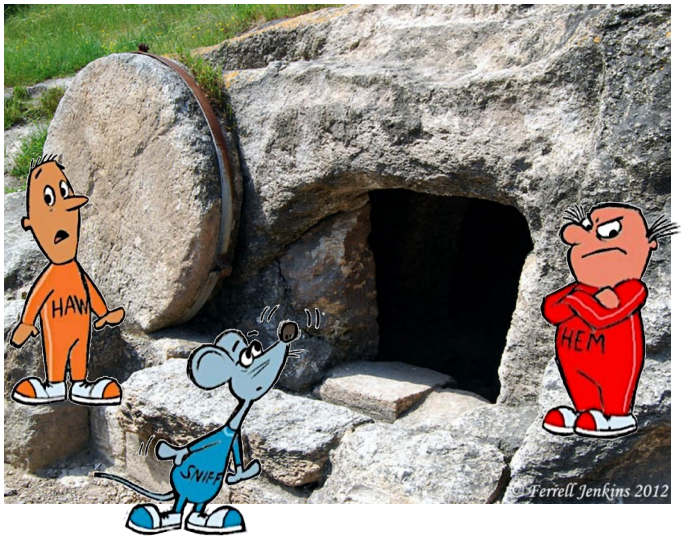
Hem – (RHS) angry, impatient, unwilling to move

Haw – (LHS) scared stiff, but thinks

Sniff – (LM) always using their tools

Scurry – (RM) always on the move to discover new things

Protecting things



First Attempt at Security

- Put large boulders in front of our caves
- Someone figured out how to move them
- Repetitive journey - find the better lock

Our first attempts <Click> at security involved hiding our stuff by moving a big boulder in front of our caves <Click>. This took a lot of work to roll the boulder and get just right.

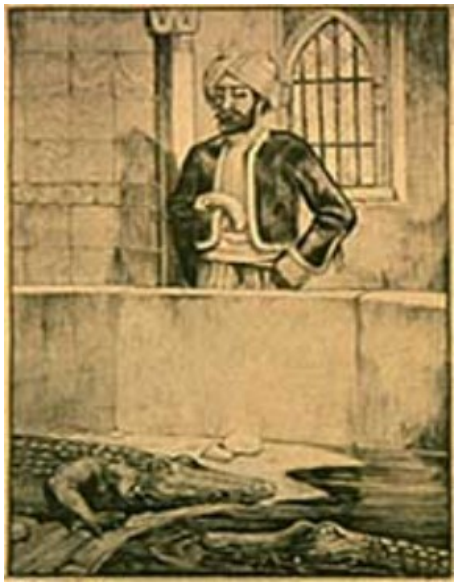
However <Click>, someone figured out how to move our rock and get to our stuff anyway.

<Click> This scared Haw who said, “What will we do now?”
<Click> Hem was mad and said “We’ll move the rock back of course. They won’t figure it out again!”
<Click> Sniff knew this was a mistake, though, and
<Click> Scurry said, “Let’s find a new way to protect our stuff!”

So, this is the story we have repeated throughout history <Click>. We create a lock, someone breaks it, so we make a new lock.

Let’s visit some of these innovations over time.

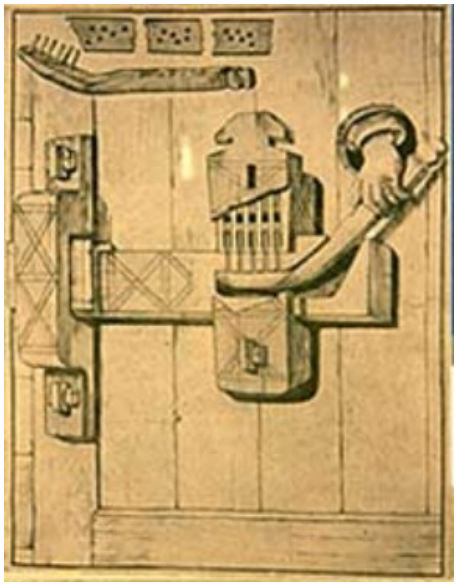
Protectors



We first utilized protectors to guard against a thief. Human guards were error prone and unreliable, so we started with <Click> man's best friends trained to attack intruders.

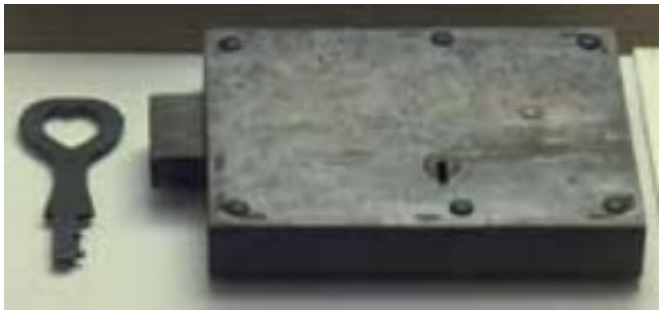
<Click> The story goes that in India, they placed their valuables in pools filled with partially starved crocodiles. In both cases, drugging or killing the animals was an effective means of bypassing the lock.

Locks and Lockpicks



Moving to a non-living protection method was the next evolution. At first we used <Click> seal locks that would be able to show evidence of tampering. Although a deterrent, it didn't actually prevent someone from gaining access. <Click> In the 8th century BC in Persia one of the first wooden locks was used in a method very similar to a tumbler lock that we use today.

Locks and Lockpicks



As materials improved, we moved to <Click> metallic tumbler locks and <Click> rim locks. Both proved tricky for criminals to bypass, but not impossible. Today, we see many hobbyists picking locks like these for fun.

Value of things and information

- Information became valuable
  - War plans
  - Hidden treasure
  - Hunting / farming grounds
- Necessary to transmit
  - Get strategy to front lines
  - Remote allies
- Easy to intercept

At some point in history, we started to realize that in many circumstances, <Click><Click><Click><Click>information can be much more valuable than possessions.

Information <Click><Click><Click> also needs to be transferred in some way or another for it to be useful.

This lead <Click> to problems with information being intercepted and used for malicious purposes.

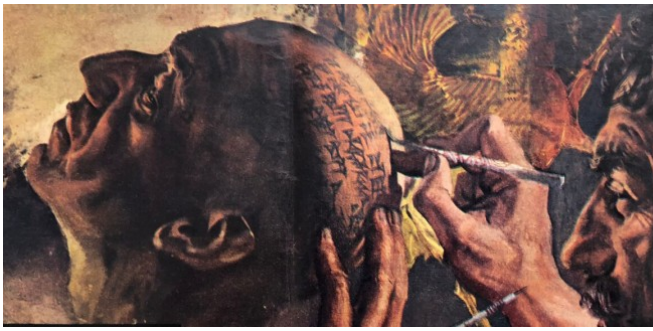
Hiding info in plain sight

- Novel schemes
- Useless when discovered
- Secrets can be bought

Which lead us to invent methods to hide information in plain sight.

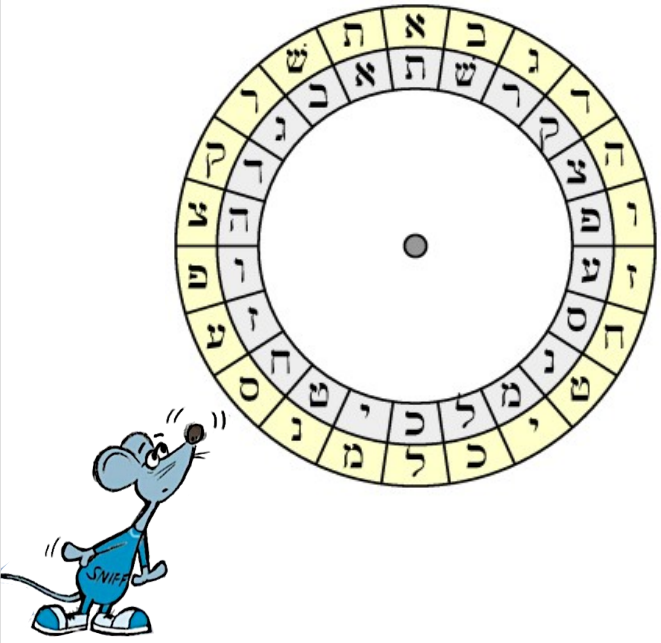
<Click>
Many of these were novel schemes. They worked, but
<Click>
Once discovered how they worked, they were useless.
And of course, <Click> secrets can be bought.

Hiding info in plain sight



During the Classical Era <Click>, the Spartans were known to use Scytale (skit-a-lee) Cipher's to transmit message by a leather belt wrapped around a pole. There are even classical writers <Click> who indicate that in 500 BC, Histiaeus tattooed secret messages onto his slaves shaven heads, waited until their hair grew back, and then sent them to deliver the messages in secret.

Encoding



In other parts of the world, they were coming up with their own ways of encoding secret messages, <Click> like Atbash in Israel in 500 BC, and the <Click> Polybius Square in 200 BC.

All of these methods were trivial to break once discovered how they worked. So, our heros had to move on to something new.

Symmetric Key Cryptography

- Single key for both encryption and decryption
- Simple
- Powerful
- Key distribution issues
- Number of keys difficult

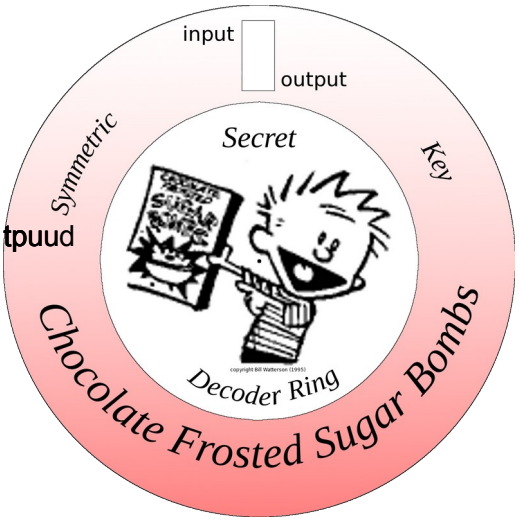
How can we hide information in a way that is known without it being discoverable? Much like a lock, we need a key that is kept secret and only the keyholders can <Click> encrypt and decrypt the message.

Having a system like this gives us many desirable <Click> properties <Click> that can help transfer secret messages.

However, how do we keep those <Click> keys safe? How do we make sure only those that should, have the keys. And how to you <Click> keep track of all those keys? Every conversation you have with a different person needs a new key!

Symmetric Key Cryptography

tpuud

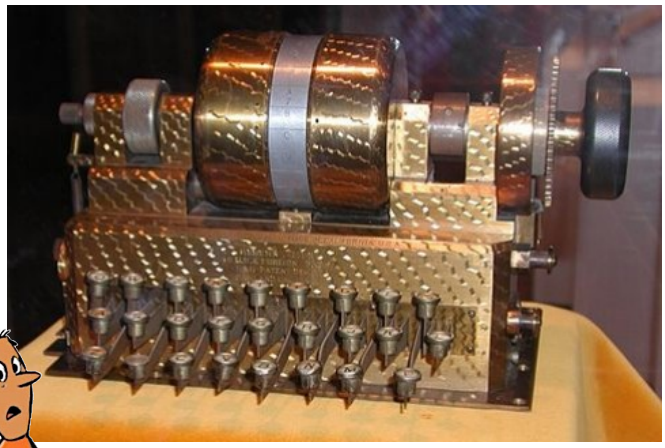


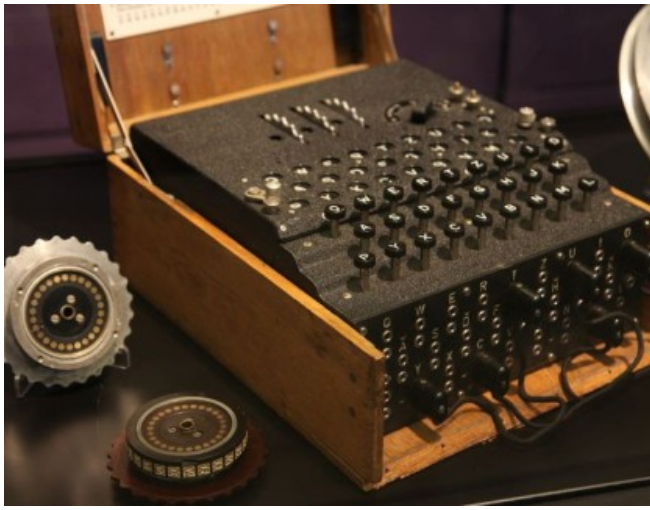
Jimmy

Here we've created a simple substitution cipher <Click><Click> where we decrypt our simple message <Click> by rotating the dial <Click> and writing down each letter.<Click><Click><Click>

The nice thing about this type of cipher is that the same key can be used for encrypting as well <Click>, which you can see when I reverse the process.

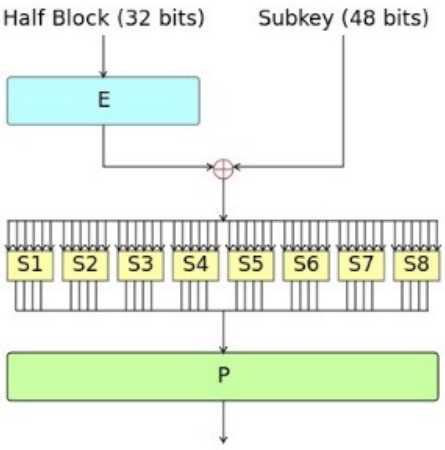
Symmetric Key Cryptography

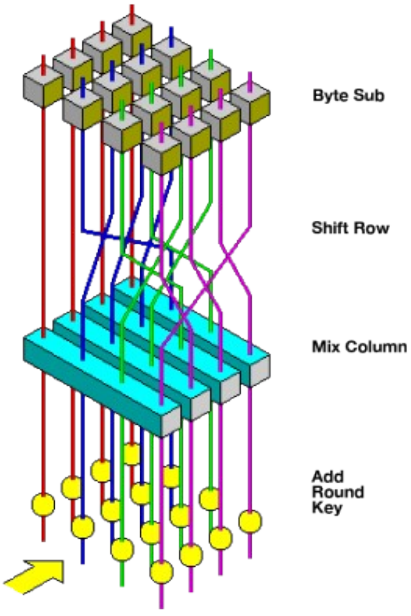




Before modern computers, many types of machines were created in the early 20th century. <Click> the Hebern Rotor Machine in 1921 failed as product, only selling a few machines to the US Navy in 1931. A more famous rotor machine was invented by the Germans in 1923. <Click> The Enigma Machine was actively used for transmitting secrets during WWII. In 1932, the Enigma machine was defeated by a Polish mathematician.

Symmetric Key Cryptography



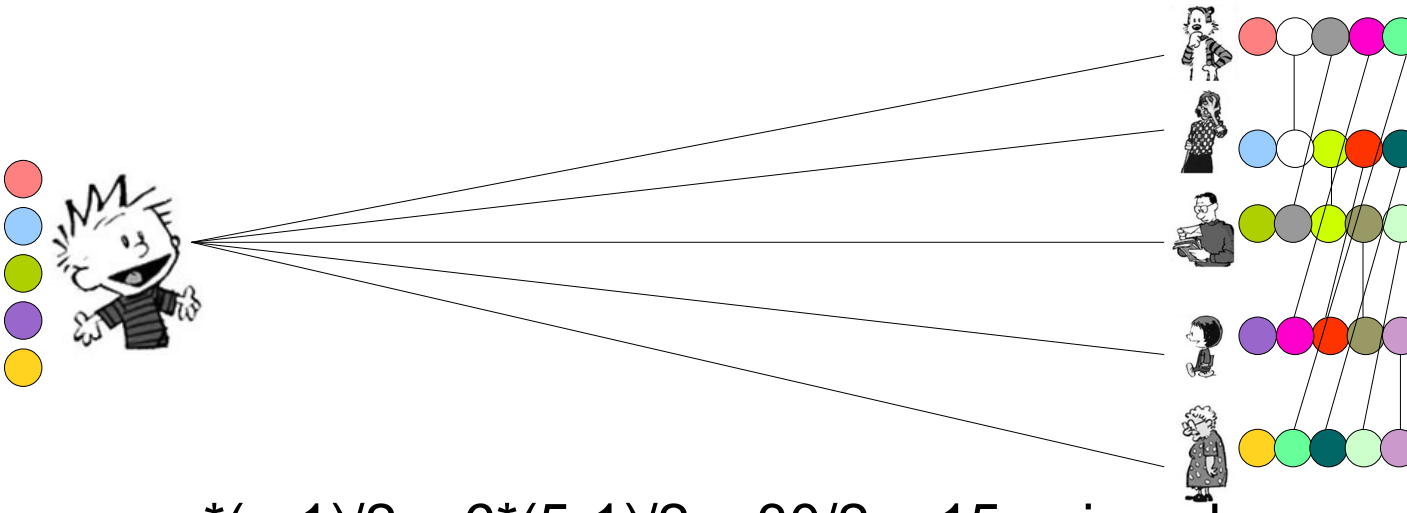


The Data Encryption Standard (DES) <Click> was created in 1975 and utilized mathematics for the scheme to encrypt and decrypt based on a private key. The NSA approved DES, but with a small key size that they could brute force if necessary. By 1999, public organizations showed that they too could break DES leading us to the use of triple DES (3DES), which is vulnerable to some theoretical attacks.

This brought us to the adoption <Click> of the Advanced Encryption Standard (AES) in 2001. AES-256 is considered to be quantum resistant as well.

Either way, the key distribution remains an issue even with AES-256, which leads us to our next topic.

Symmetric Key Cryptography



n*(n-1)/2 = 6*(5-1)/2 = 30/2 = 15 unique keys

Let's say that we have Calvin who wants to send a secret message to Hobbes. He creates a key and shares it with Hobbes. He'll need to do the same with each person in his life as well to keep all the messages secret. But, if Hobbes wants to send a secret message to Calvin's Mom, he'll also need a separate key. In fact, for everyone in Calvin's life to communicate about how he is misbehaving, they'll end up having to create 15 keys for 6 people.

May not seem significant, but remember, for 100 people, you'll need almost 5000 keys (4,950).

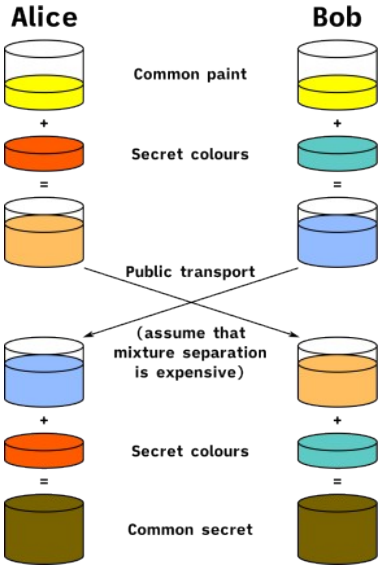
Keeping track of all those keys turns into a nightmare.

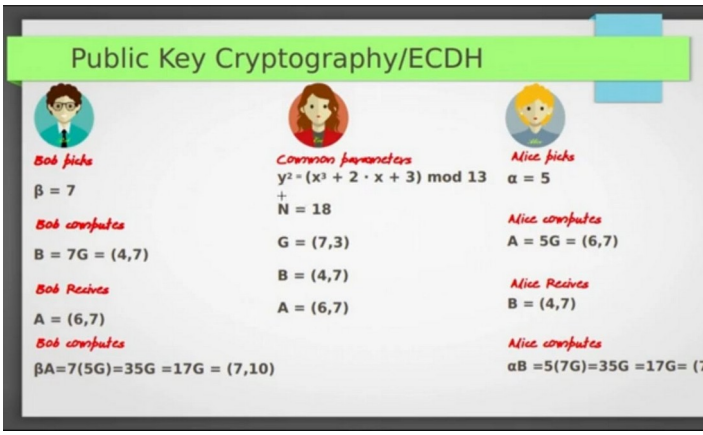
Key Exchange

- Generate a unique secret key
- Never transfer it over the wire

Another problem with Symmetric Key Cryptography is how to share the key securely. One method is to utilize a key exchange protocol. It allows you to <Click> generate a one time use, random secret key. <Click> And then transfer enough information to so that both parties can know the secret key without ever having transferred it over the wire.

Key Exchange (Diffie-Hellman)





Whitfield Diffie and Martin Hellman came up with such a <Click> scheme in 1976 utilizing discrete logarithms. In 1985 <Click>, a method of using Elliptic Curves along with Diffie-Hellman was created as well. Both are popular today. However, there are times when you want to encrypt and decrypt more than just a secret key. In those cases, Asymmetric Cryptography is used.

Asymmetric Key Cryptography

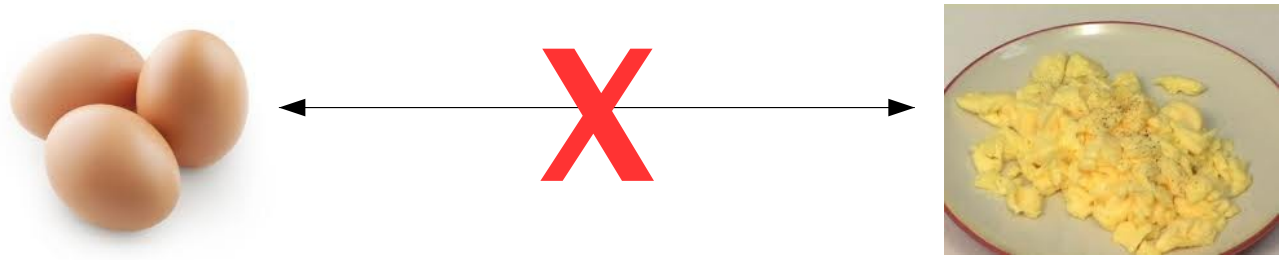
- Split public and private keys
- Key distribution easier
- Number of keys manageable
- Slower
- Authentication issues
- Relies on a one-way function (Theoretical Math)

Using the idea of splitting <Click> a key into a public half shared by all, and a private half kept secret corrected a lot of issues surrounding key distribution <Click>. Now you only needed one private key and you could share your public key with the world <Click>. Unfortunately, this type of encryption <Click> is slower and is typically only used to share a secret key that is used for symmetric key encryption.

Another issue with this is verifying the authenticity <Click> of a key holder, which is a problem we solve with a Public Key Infrastruction, or PKI.

The beauty of Asymmetric Key cryptography is the use of a <Click> one-way function which uses a mathematical construct.

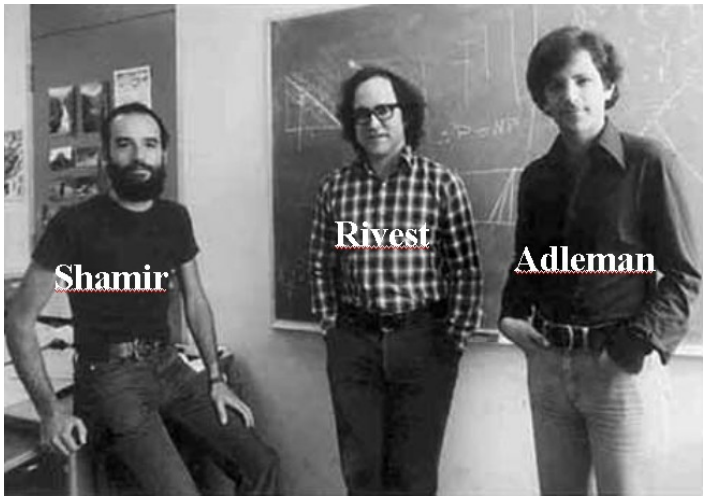
One way function

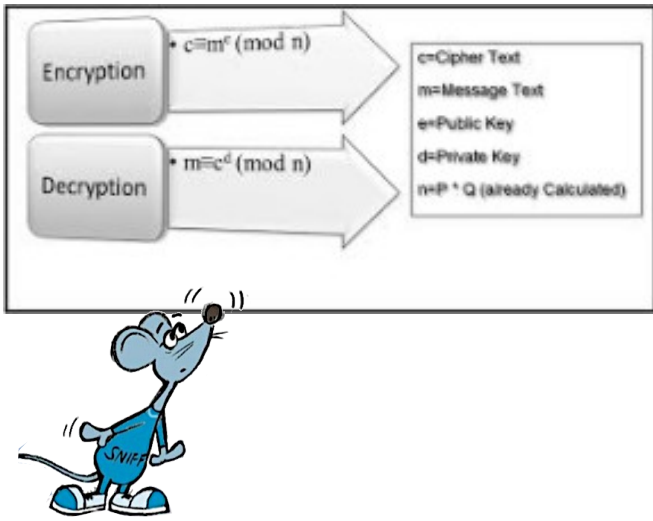


Easy to make scrambled eggs, but it is practically impossible to de-scramble eggs without some sort of a magic de-scrambler.

We want something similar, where it is easy to go one way, but nearly impossible to go back the other way without some other piece of knowledge.

RSA

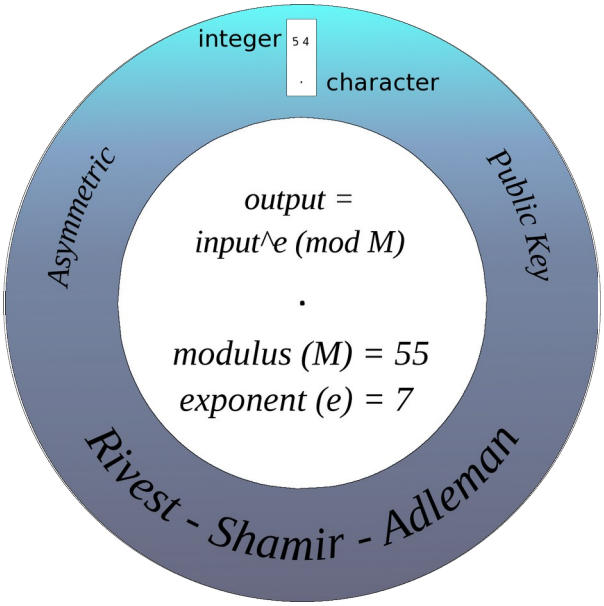




In 1977, <Click> Ron Rivest, Adi Shamir and Leonard Adleman created the RSA algorithm. <Click> It relied on the one-way function of factoring large composite numbers made by multiplying two primes together, also know as a semi-prime. Multiplying is easy, factoring is hard.

One way function for RSA

Jimmy



14 13 18 18 3

One way function for RSA

14 13 18 18 36

14 13 18 18 3

One way function for RSA

11 14 13 18 18 36

13

18

18

36

One way function for RSA

$14^7 \bmod 55 = 105413504 \bmod 55 = 9 = \text{“g}$

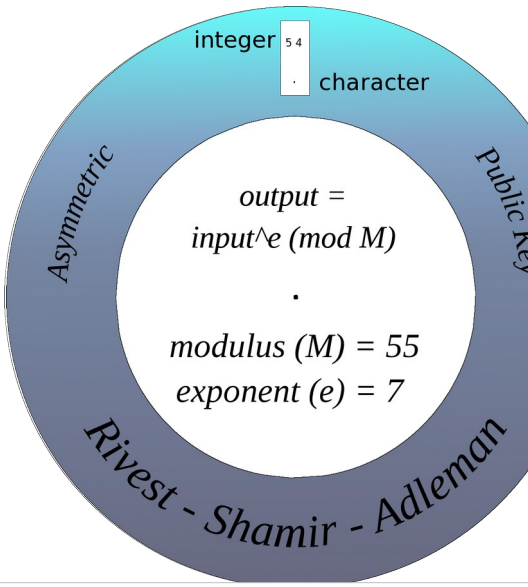
$13^7 \bmod 55 = 7 = \text{“e”}$

$18^7 \bmod 55 = 17 = \text{“l”}$

$18^7 \bmod 55 = 17 = \text{“l”}$

$36^7 \bmod 55 = 31 = \text{“v”}$

E(Jimmy) = gellv



One way function for RSA

$9^{23} \bmod 55 = 14 = \text{“J”}$

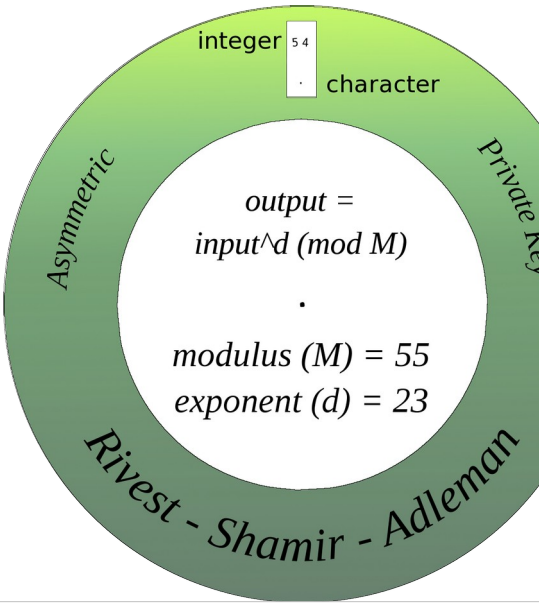
$7^{23} \bmod 55 = 13 = \text{“i”}$

$17^{23} \bmod 55 = 18 = \text{“m”}$

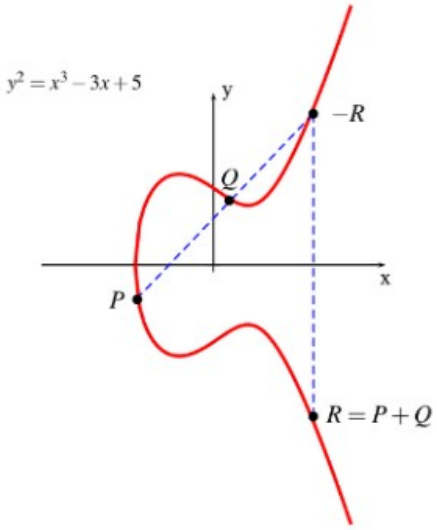
$17^{23} \bmod 55 = 18 = \text{“m”}$

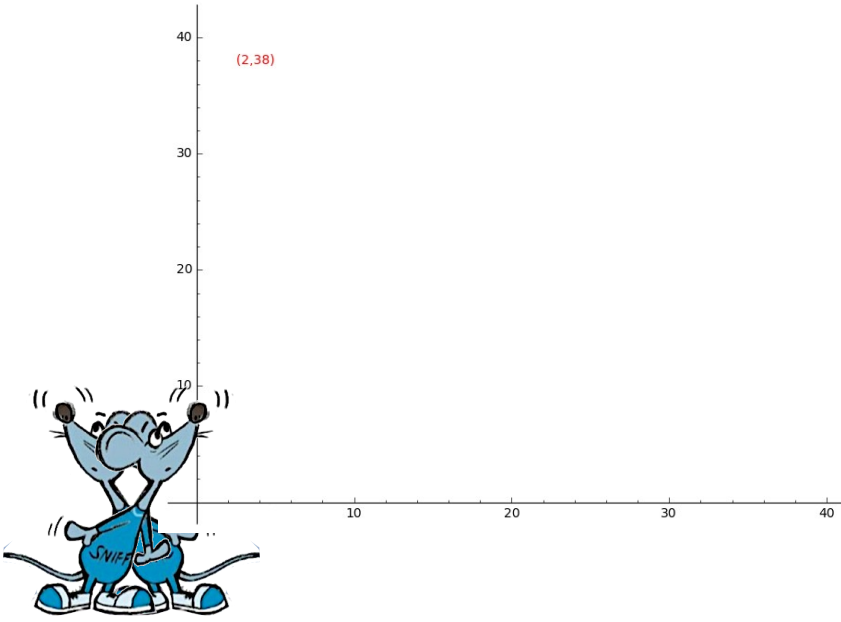
$31^{23} \bmod 55 = 36 = \text{“y”}$

D(gellv) = Jimmy



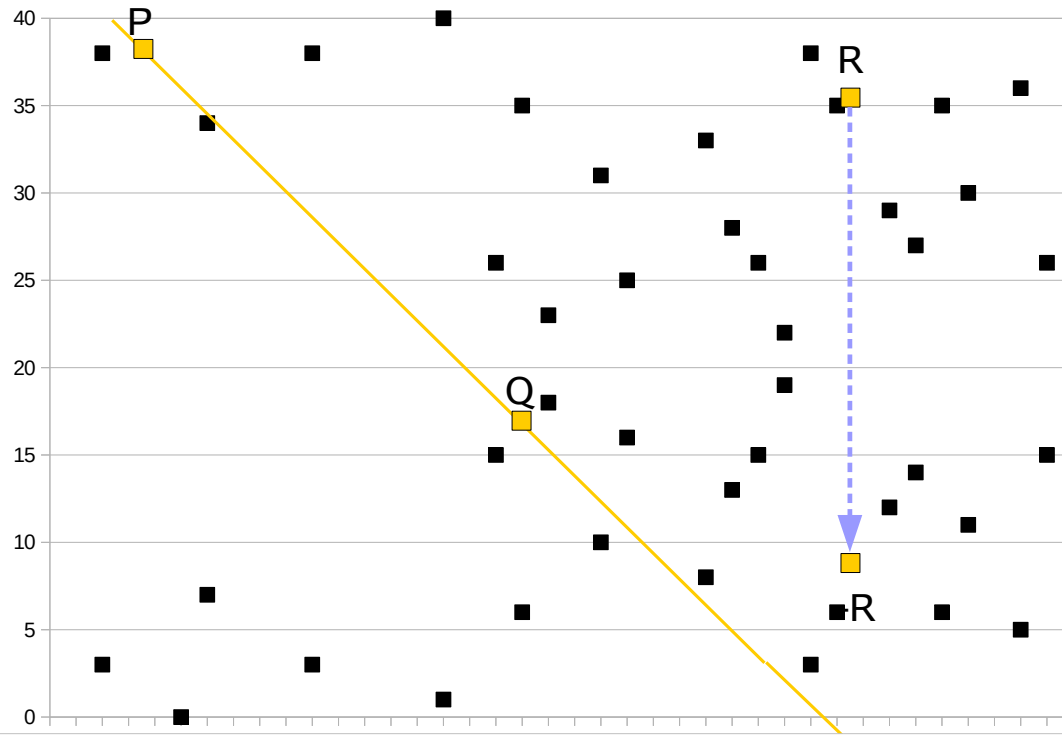
Elliptic Curve Cryptography





In 1985, Elliptic Curve Cryptography was created which relies on the mathematical properties of an Elliptic Curve. It's smaller keys and faster mathematics make it ideal for use on small devices without a lot of computing power.

x	$y^2 \pmod{41} \equiv x^3 - x + 3 \pmod{41}$
2	3; 38
5	0
6	7; 34
10	3; 38
15	1; 40
17	15; 26
18	6; 35
...	…

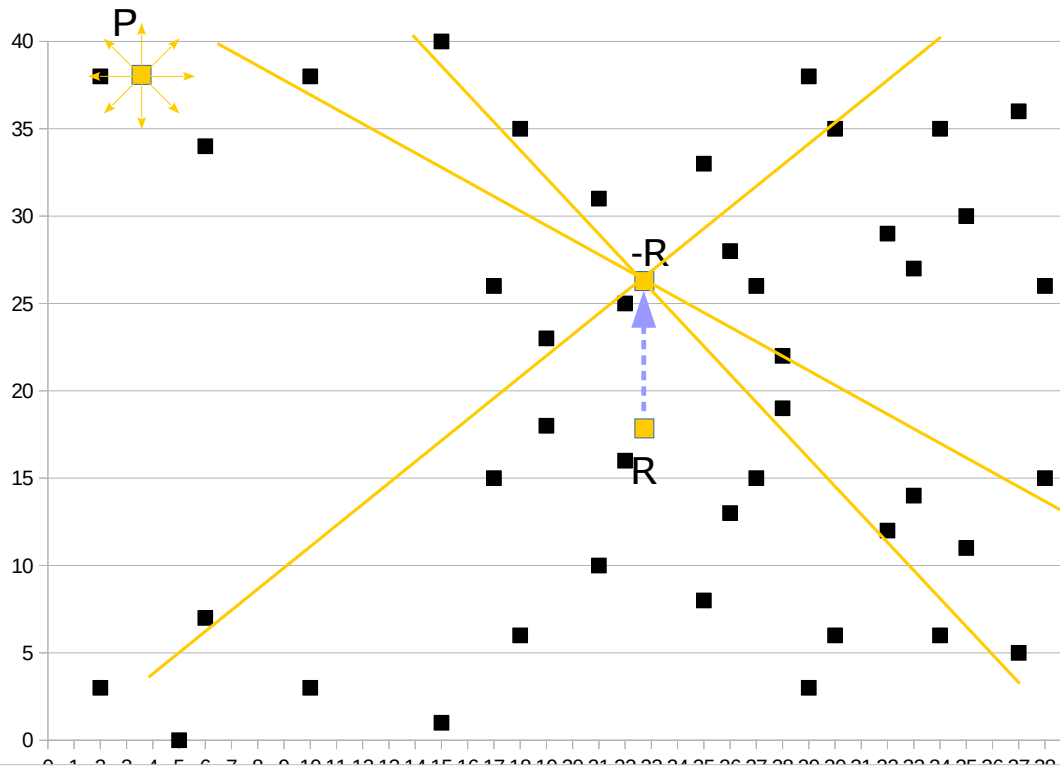


P ⊕ Q ⊕ R = 0

P ⊕ Q = -R

The one way function for ECC involves plotting the graph in a finite field and then doing what is called point addition. By drawing a line through points P&Q you can jump back to the top of the graph and eventually draw through point R. Then you can flip across the center axis to find the negative R value which is the answer.

x	$y^2 \pmod{41} \equiv x^3 - x + 3 \pmod{41}$
2	3; 38
5	0
6	7; 34
10	3; 38
15	1; 40
17	15; 26
18	6; 35
...	…

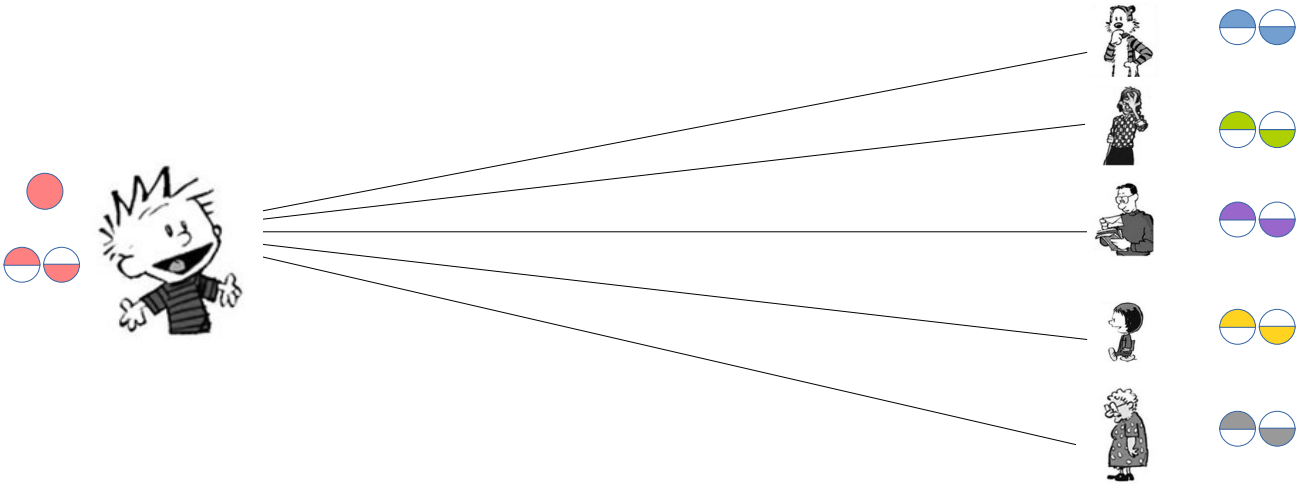


P + Q = -R

P + Q + R = 0

Reversing this flow, however is difficult. Even if you know point P and point R, you don't know which direction to draw in order to find your point Q. This is the one way function of ECC.

Asymmetric Key Cryptography



2*n = 2 * 6 = 12 unique keys

So for asymmetric key cryptography, sharing keys between Calvin <Click> and his friends <Click> becomes much more manageable. Calvin creates a key <Click> and splits it into two <Click><Click>, a public half and a private half. His friends then repeat this process <C5>. Sharing public keys <Click> is easy as it doesn't matter if they are stolen.

<Click> Remember, for 100 people Symmetric crypto would require about 5000 keys (4950).

For Asymmetric crypto, we only need 200.

Quantum Computers

- Use qubits instead of classical bits
- Qubits can be in more than one state at the same time
- The state of a qubit is unknown until you observe it
- Qubits are fragile and interference can put them into an error state
- Error rates slow down the development of quantum computers

Quantum computing uses quantum mechanical properties such as superposition and entanglement to solve problems. <Click>Much like a bit in classical computers, quantum computers use qubits to represent data. Qubits have the <Click> special property of being able to exist in multiple states at the same time. Once observed <Click> the qubits reveal their final state in a probabilistic manner. <Click> Qubits are prone to errors due to many factors, <Click> which slows down the efficacy of quantum computers.

Shor’s Algorithm

- Makes factoring large semiprimes obtainable
- Another algorithm for solving the discrete logarithm problem
- And yet another for the period finding problem
- With proper quantum computer, RSA, DH, ECC, ECDH all become obsolete

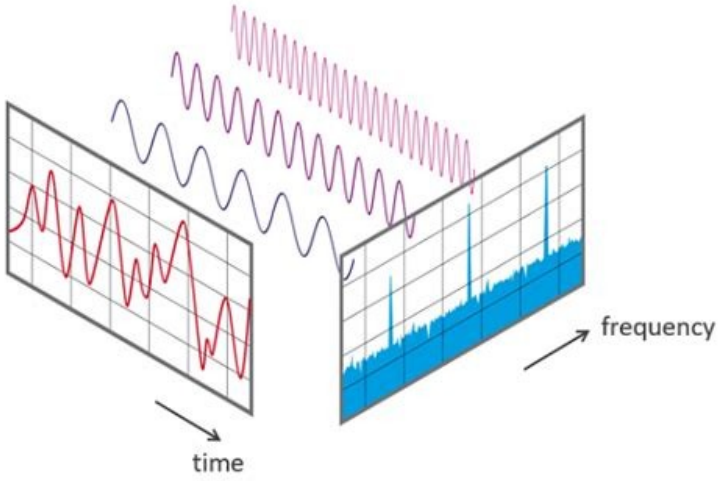
Peter Shor created an algorithm in 1994 that used a theoretical quantum computer to <Click> drastically reduce the time needed to factor semiprimes back to their original primes.

He created other algorithms to solve the <Click> discrete logarithm and <Click> period finding problem in a shorter amount of time as well.

With the correct hardware, <Click> these algorithms could render all of the previously discussed key exchange and asymmetric key cryptography systems unusable.

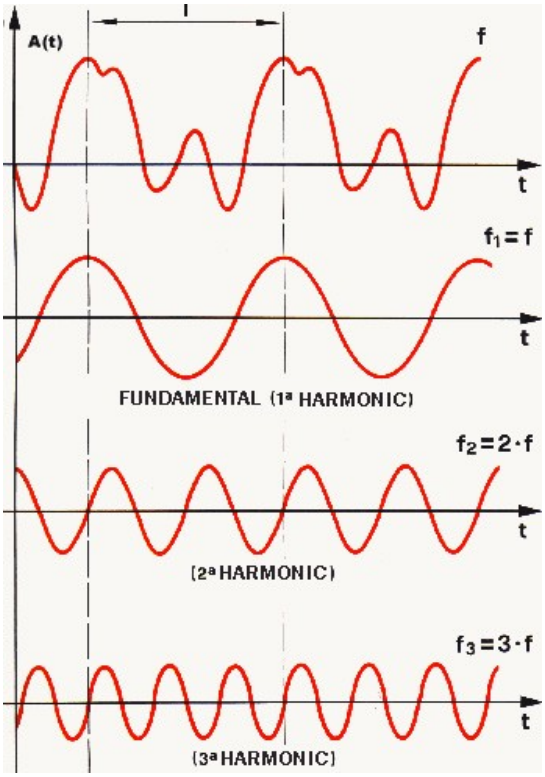
The concepts of Shor’s algorithms are complex, but here is a brief overview of how they work.

Fourier Transform

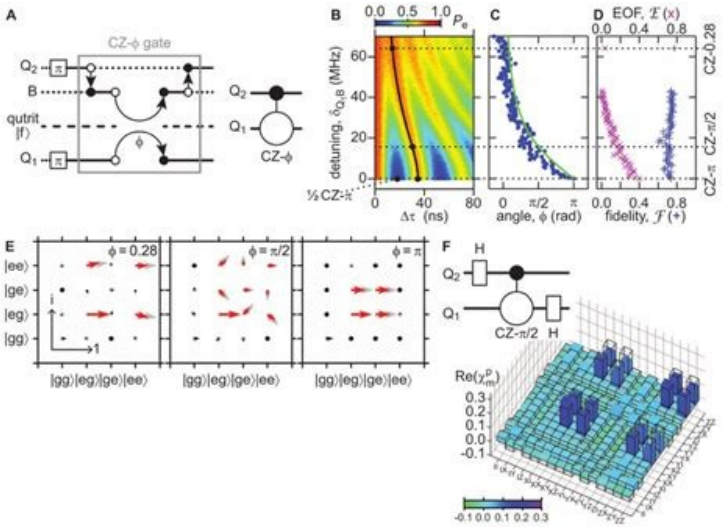


A Fourier Transform is a way to convert a complex wave into its component waves. On the left of this slide we see a complex wave over time being transformed into a frequency graph on the right.

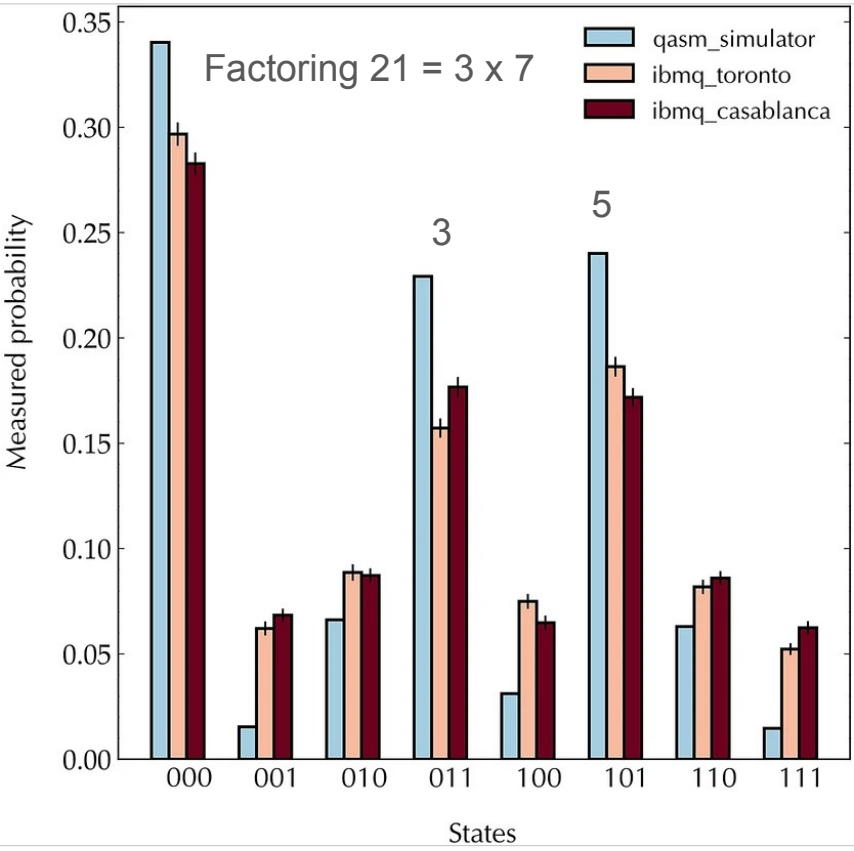
Fourier Transform



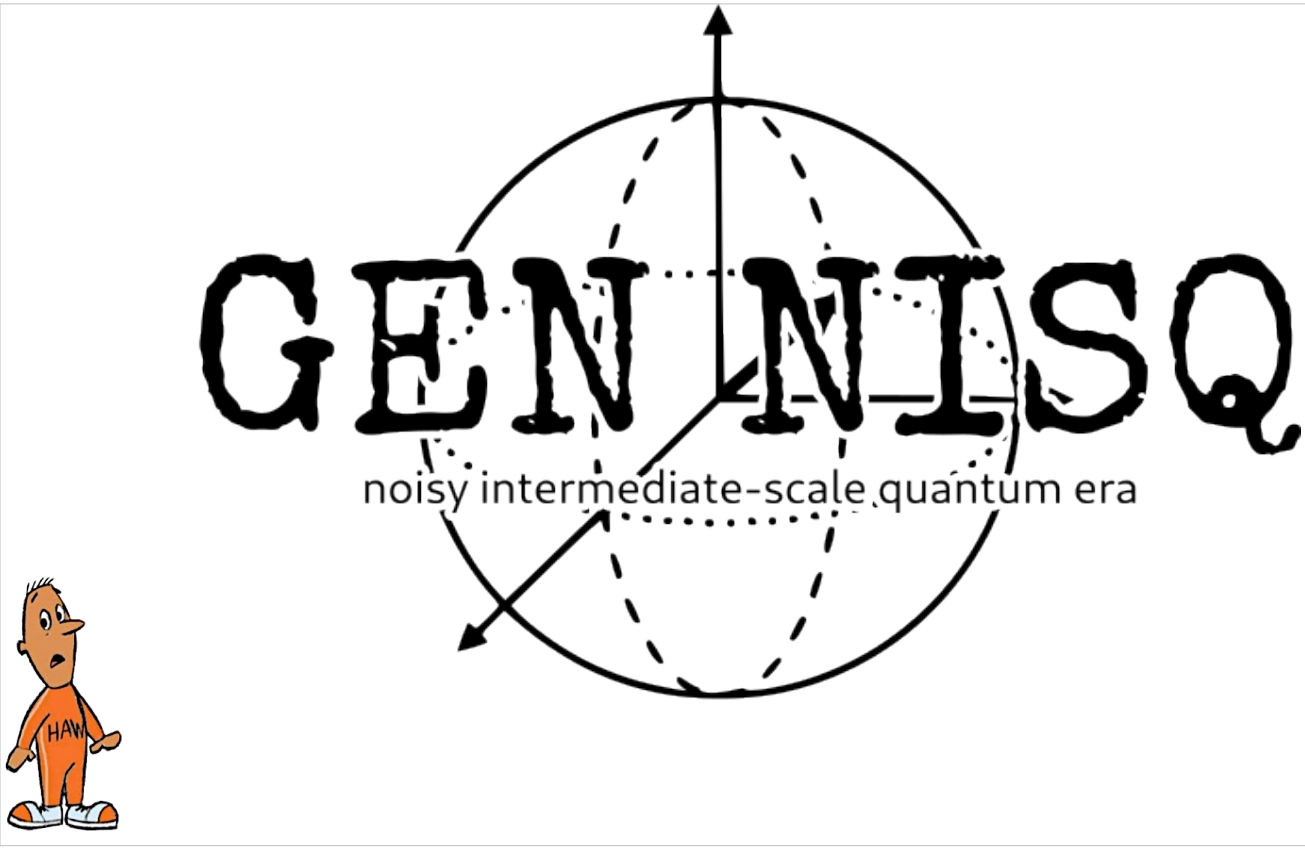
This is useful in breaking down waves of any kind, like sound waves to determine how they are formed.



Utilizing Quantum Fourier Transform, we can sequence the probability amplitudes for all the possible outcomes upon measurement. This ability to test everything with a single measurement shows us the power of quantum computers. Notice, that unlike discrete systems, quantum computers and qubits give us a probable answer which may change over multiple runs. The number of runs is very small, though, compared to the processing that a classical computer would need.

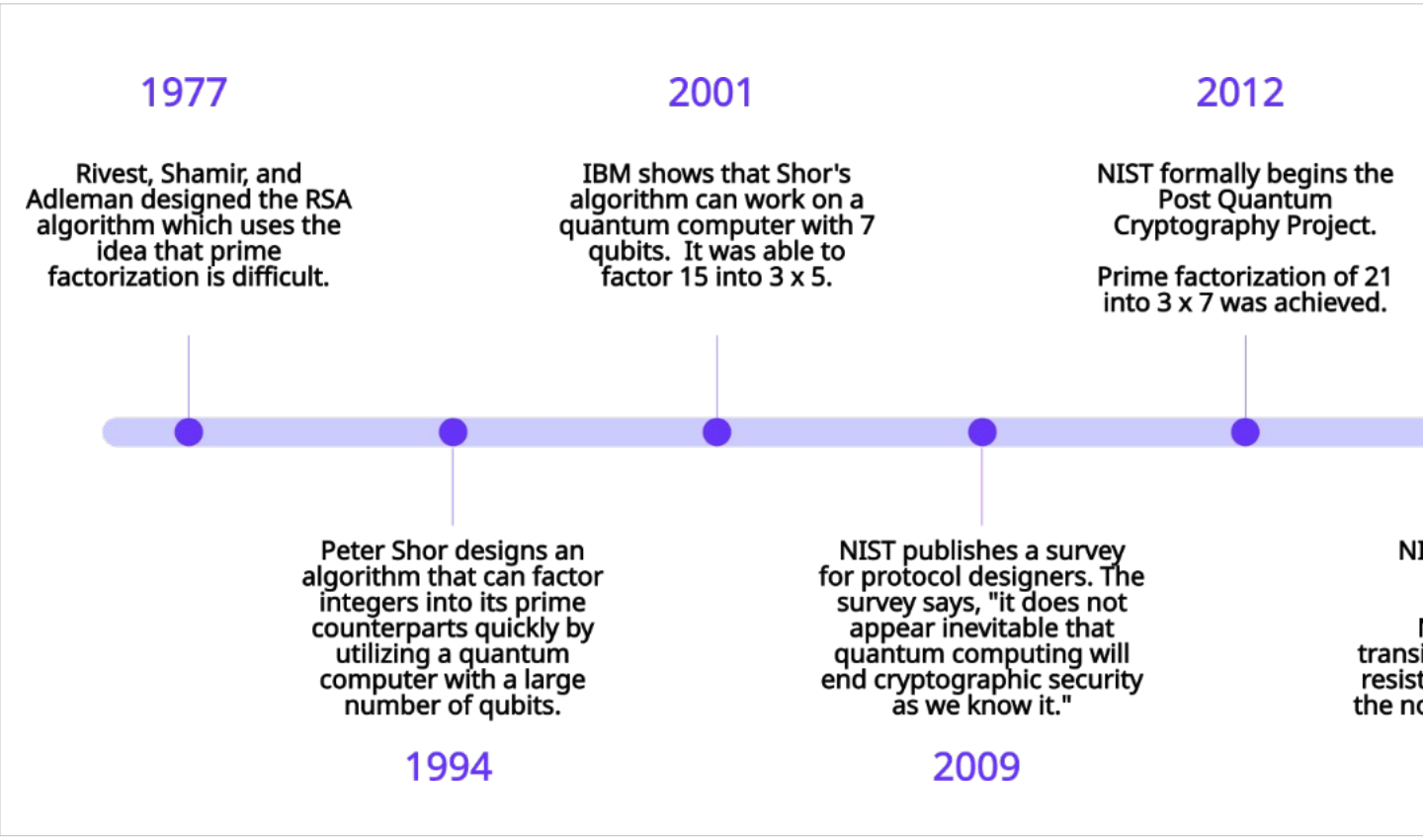


Let's talk about the errors that happen with quantum computers. Here is the results of a 5 qubit quantum computer attempting to factor 21 into its component primes 3 and 7. As you can see, the measured probability of 0 is the highest given, with 3 and 5 coming in close second and third. The 0 result is an error state and should be ignored. Given 4 as the initial guess, the IBM casablanca test came out favoring 3 as one of the primes, which was the desired result. This experiment is considered as being successful in factoring of the semiprime 21 even though there are lots of error conditions to consider.



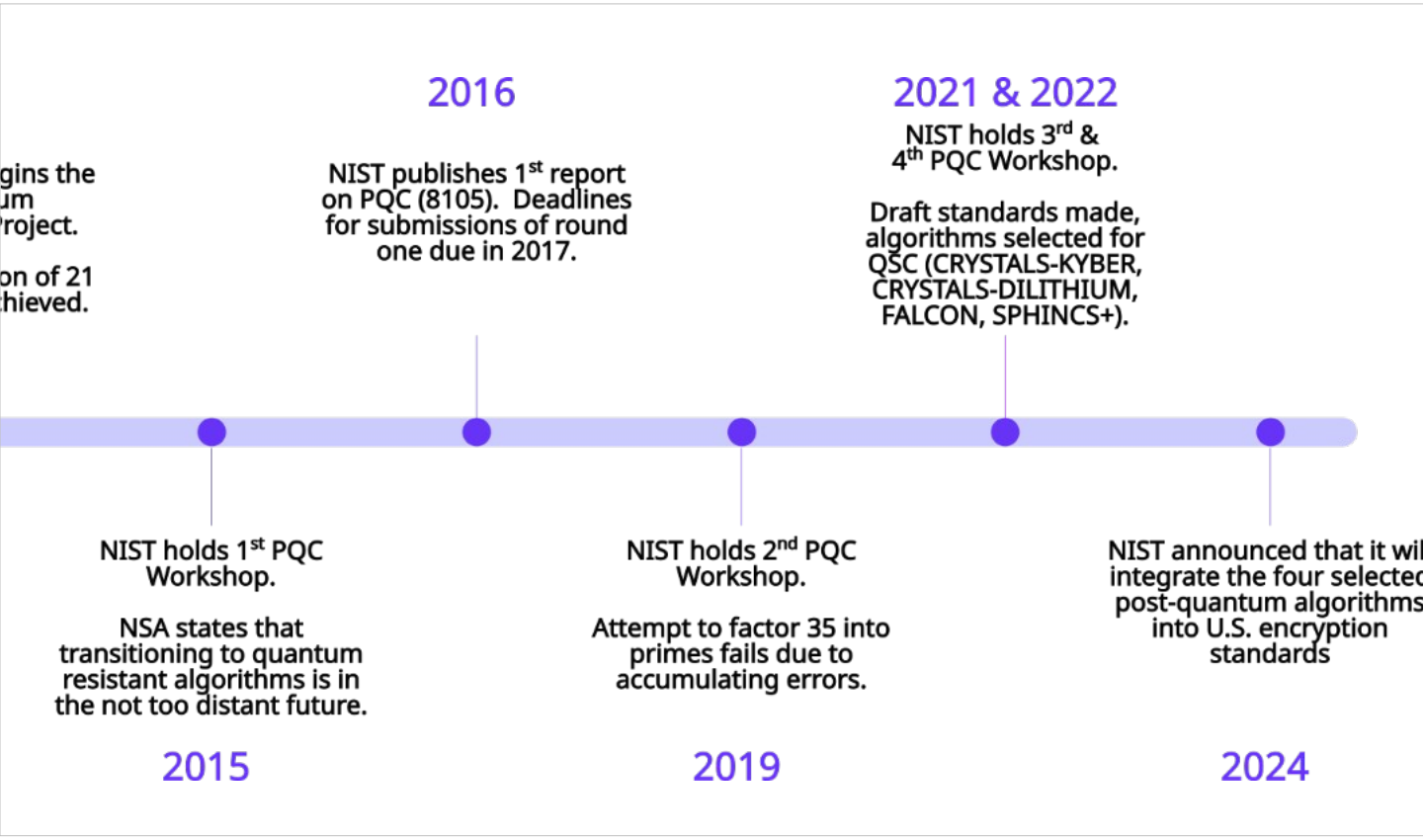
So that leads us to the question, are quantum computers ready to start breaking the Internet? It has been described that we are in the <Click> Noisy Intermediate-Scale Quantum era. I like to say that everyone alive today is part of generation NISQ, or GEN-NISQ. This is a time of innovation and investment into building better and more stable quantum computers. But, we still have time before quantum computers will be breaking the encryption that keeps us all safe today.

So why aren't I more worried about Quantum computers? To explain, we'll let's take a look at our timeline and what quantum computers have accomplished so far.



As you can see from this timeline, the RSA algorithm was created nearly a half a century ago. 17 years later, Peter Shor developed the algorithm that a quantum computer could use to break RSA. Only 7 years later, IBM was able to use a 7 qubit computer to factor a 4 bit number, 15, into its prime factors 3 and 5. 11 years after that a 5 bit number, 21, was factored into 3 x 7. <CLICK>Another 7 years goes by and in 2019 an attempt to factor a 6 bit number, 35, failed. There is a number of larger, specially chosen numbers that have been factored by a process called quantum annealing. This has not been proven as a general solution to the problem, though.

In the meantime,<CLICK> in 2009, NIST starts a survey to begin developing the next generation of quantum safe encryption algorithms. <CLICK> Fast forward to 2023, and NIST has completed several rounds of discovery and testing of various quantum safe algorithms and chosen its candidates. In 2024, we expect those algorithms to be fully ratified and that vendors will start releasing them in their products. Cloudflare, Signal, and Apple come to mind as vendors that have already adopted Quantum Safe Cryptography.



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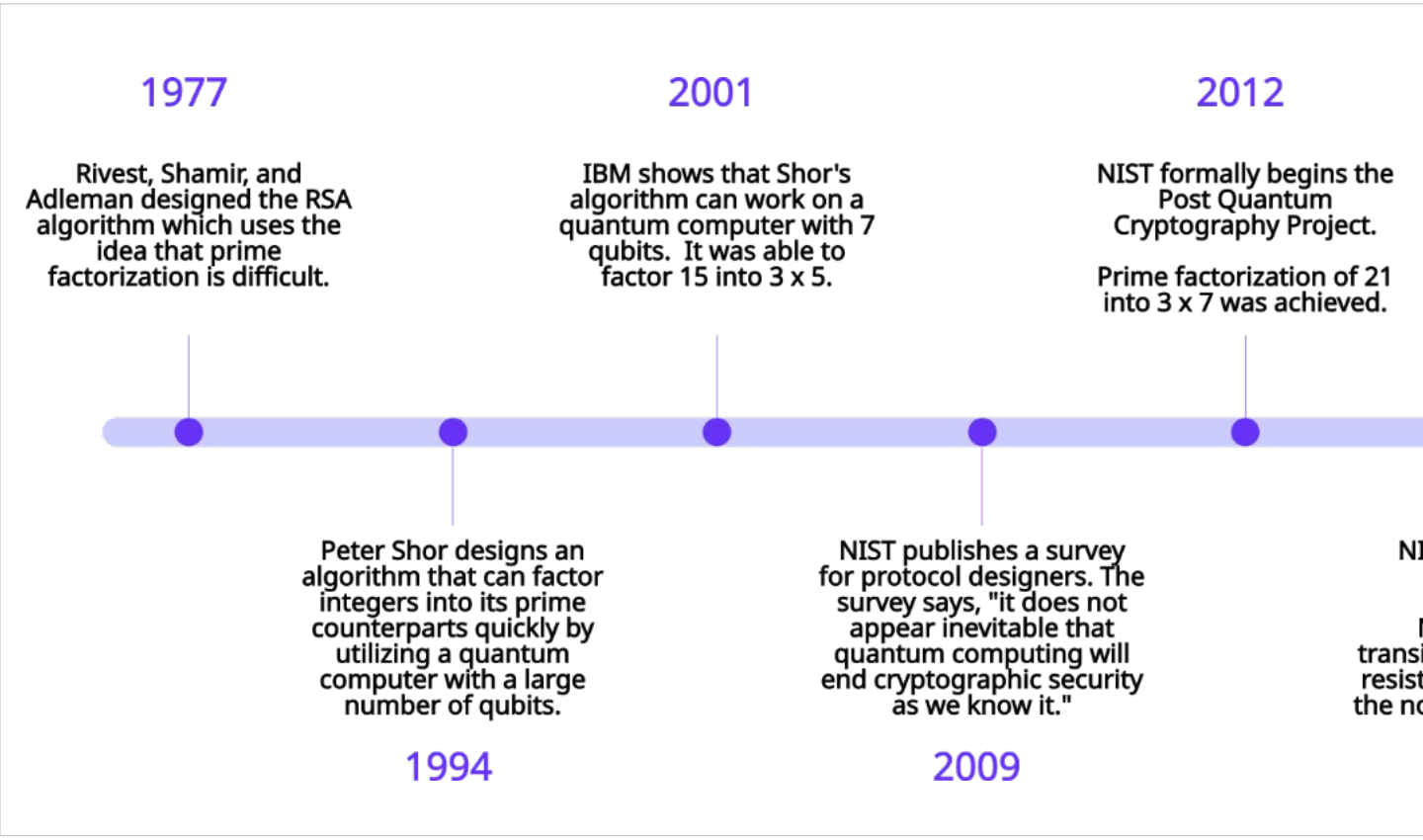

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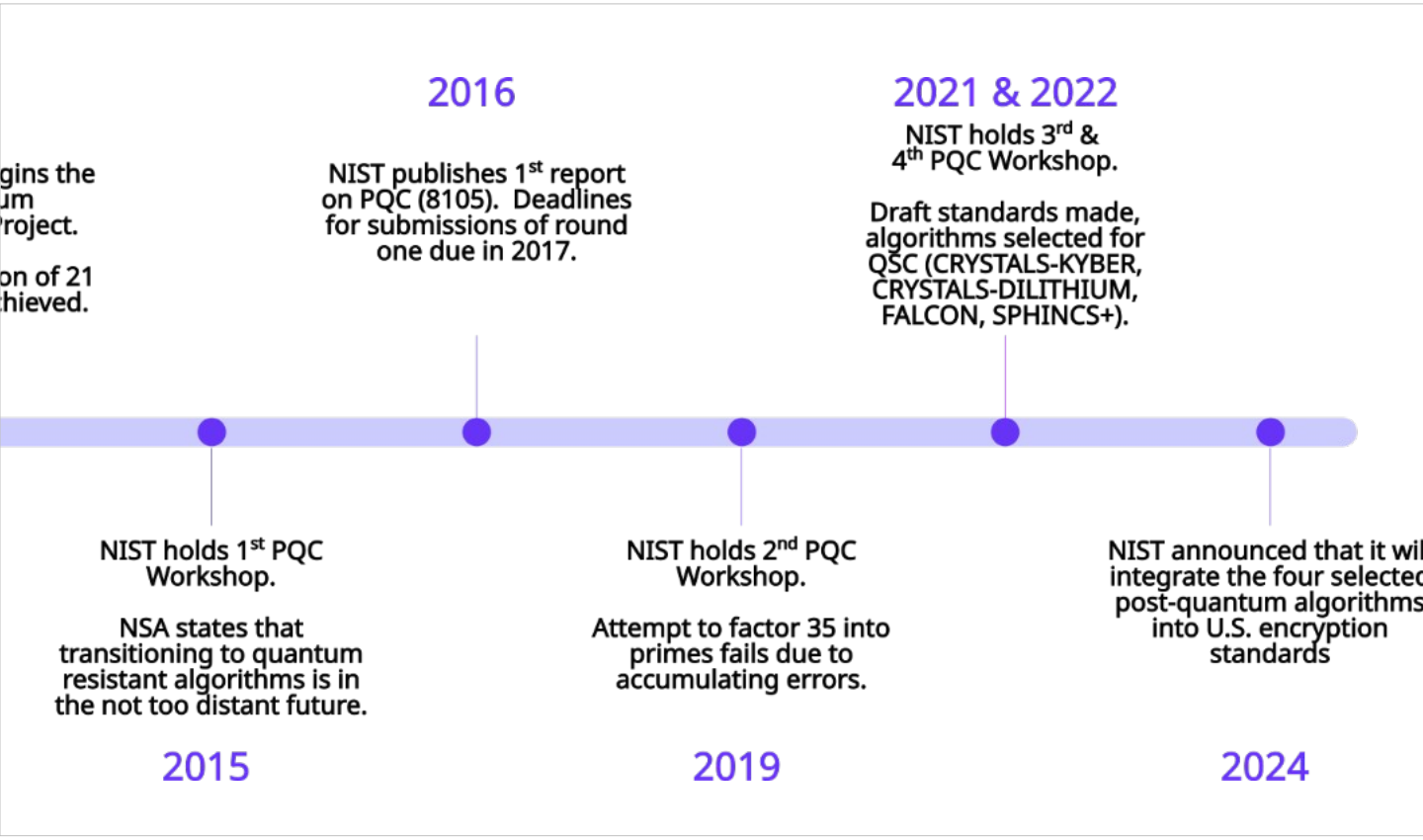

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Quantum Factored

4 bit semiprime (2001): 15
5 bit semiprime (2012): 21
6 bit semiprime (2019 - failed): 35

So, to review, this is what we've accomplished. <Click><Click><Click>Ok, this last one was a failure.

Need to factor

1024 bit semiprime:

14858031842529041742675223662020065615490358969220662
89933239251279096441074379066840500275518447762785965
12160601382625659982180758999544221868254722043619979
84526745656869867322663775380667065617182042243040564
49791211661181323805868000257522596407301217381568222
96246476504443847811940638639921190244907229

Here you can see the size of the numbers that need to be factored for us to be truly at risk.

Need to factor

2048 bit semiprime:

23042155144807033264822777505847352979234760665383921887127664352
78228085219412095936558643453832808918618527312570608206987897806
77826686707683634384826161371591122821396878931674234574664588025
31248068491920362991080654721527620276216893955001892785769536572
67267439816306389312211303562793907011141430028528465970927469108
40713994794061711394675366463723772973275703764980539097704296549
59125201782358647860679882638386416987498248726270464804391684357
18938652132696815444783098028151462344977286590749544794608585623
58276343440681884962113194327925057965815020957943883829290034086
29452106790235491702341492875849

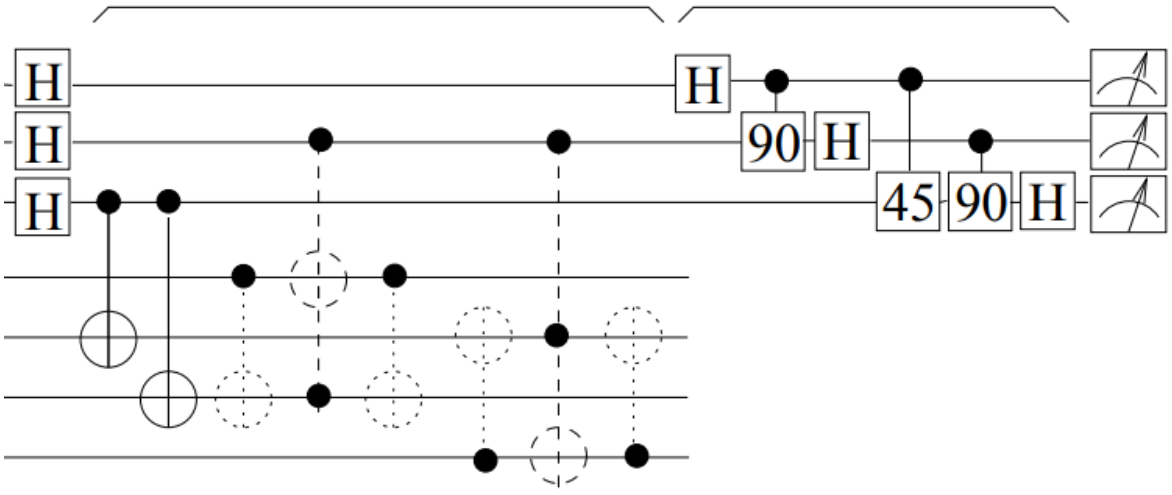
Roll of 2048bit semiprime example. NIST says good until 2030

Need to factor

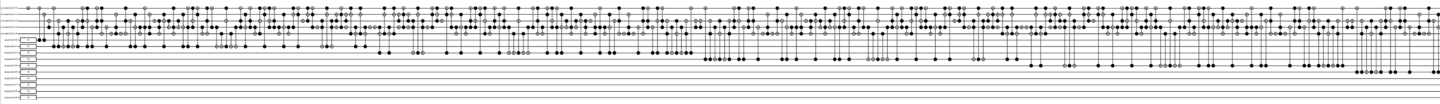
4096 bit semiprime:

895042969348578296981915910336163678732453124759533145586557604952895760317776316569158676150827486124282107892547967130332914027774243839644745256753400595926775963454953677271868790785113833576640691167921680046506876548102235826951106601104321424115479228484934247680630146283879498848910449797060157700850496337813043477561293777835401086614295601519110057733873752161156353028368807727894927096506522360815072003186182464302107329240801651864447332432227480806121176546660163477961207908730137818046855075860397970872099230128151889729620508160890782546593607782476115722199666190983162590520741299726377775088716806070106496493062874472415479023496763767874917569948669544950361493264214164541577312583731983304075229287865529835971053244670543287945198597007230421194138598762200939985241659753438228960525439886371016023854489945527427016801283327238740264623041454543856910545747681154748200516832481353745896101528766394364192199682267695484131145194250945616529523978521590091466213527524706661778437750247039074736641799486281849406242236762484545429225759181886778743331440696334172440423765256156865851502929465513715146197453647468878018363628603489424424030802769700952150094244596873055650438391281230331589881854277

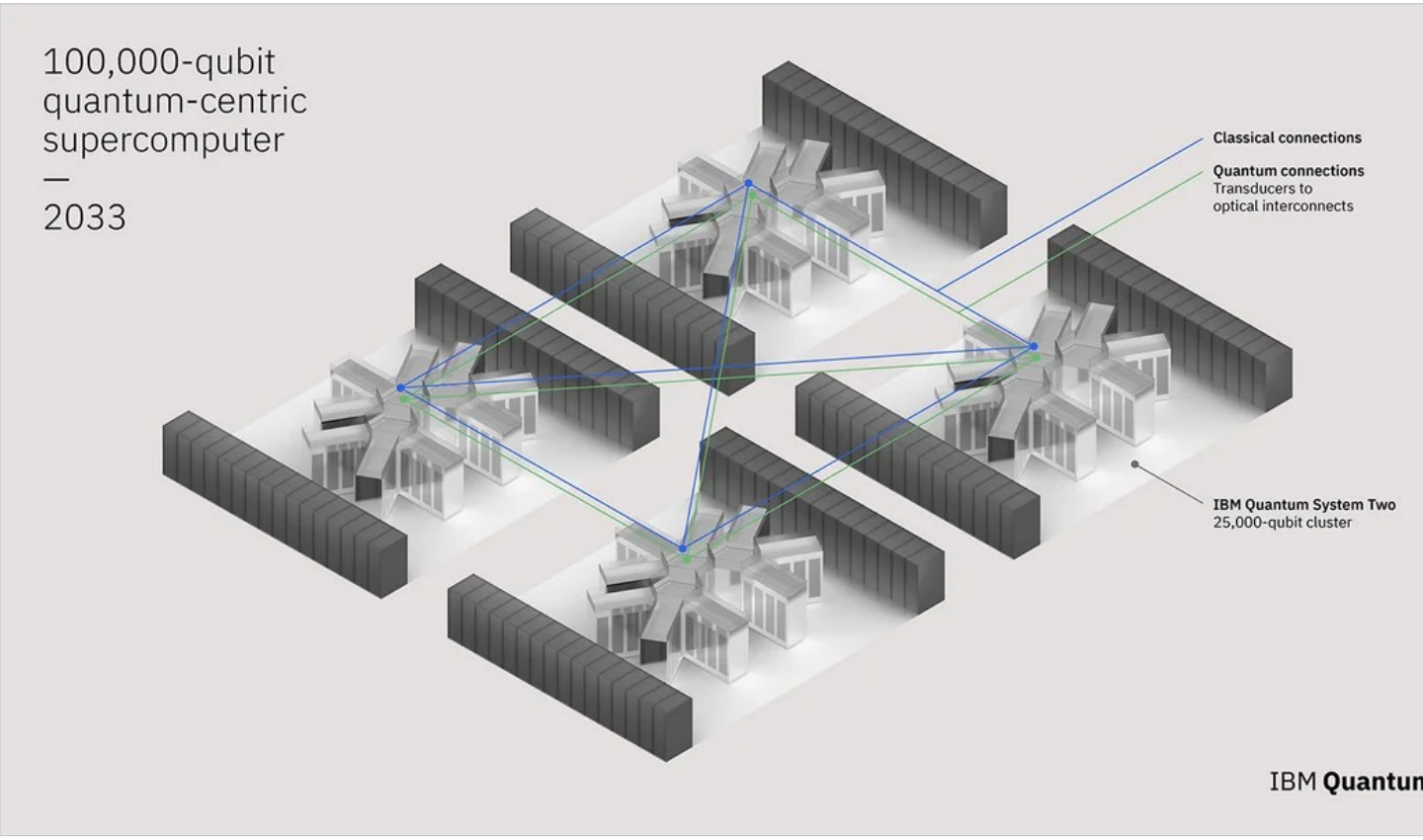
4096 bit semiprimes are not the largest number I've seen used for modern cryptography, either. I believe we will someday have quantum computers capable of factoring large numbers like this. NIST says we can wait until 2030 for 3072 bit RSA keys.



And to put that into perspective, here is the series of quantum logic gates (or quantum circuit) it takes to run Shor’s algorithm to factor 15.



Here is the series of quantum logic gates (or quantum circuit) it takes to run Shor’s algorithm to factor 21. That is 2,405 entangling gates, which is more than 100 times more expensive than factoring the 15 circuit. It grows exponentially from here.



IBM plans on having a quantum-centric supercomputer in 2033 with 100,000 qubits. Is that enough to break RSA? It depends on how error prone those qubits are.

So, what about those Post-Quantum Cryptography algorithms that NIST has been working on?

Post-Quantum Cryptography (PQC) - where are we?

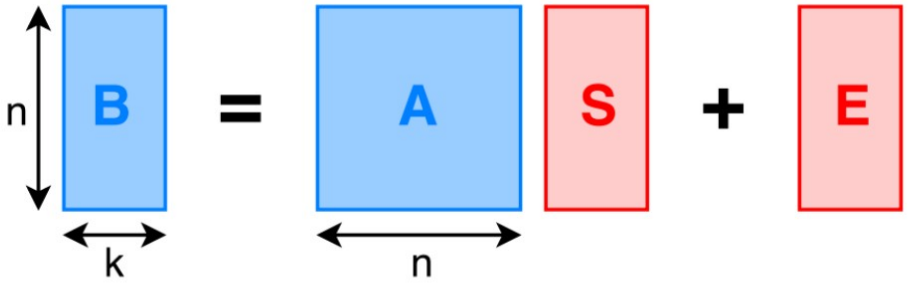
2022 NIST approves PQC encryption and signature algorithms

- CRYSTALS-Kyber (general encryption) - ML-KEM
- CRYSTALS-Dilithium (signature) - ML-DSA
- FALCON (signatures for smaller applications) - FN-DSA
- SPHINCS+ (based on a different mathematical model) - SLH-DSA

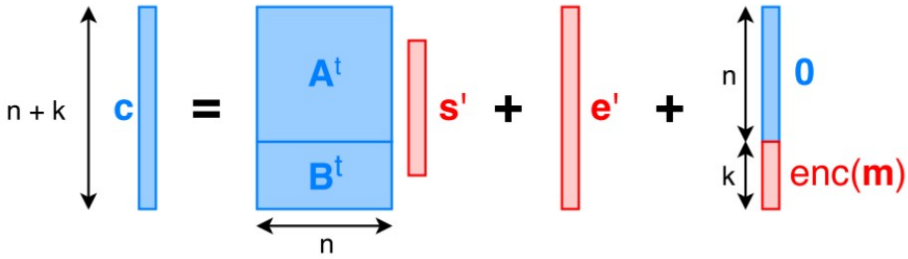
<Click> NIST made its approvals of the Quantum-Safe Algorithms <Click> CRYSTALS-Kyber for encryption, <Click> CRYSTALS-Dilithium, FALCON, and SPHINCS+ for signatures.

Public parameter $\mathbf{A} \leftarrow \mathcal{U}(\mathbb{Z}_q^{n \times n})$

KeyGen()



Encrypt$_{\mathbf{b}}(m \in \{0,1\})$

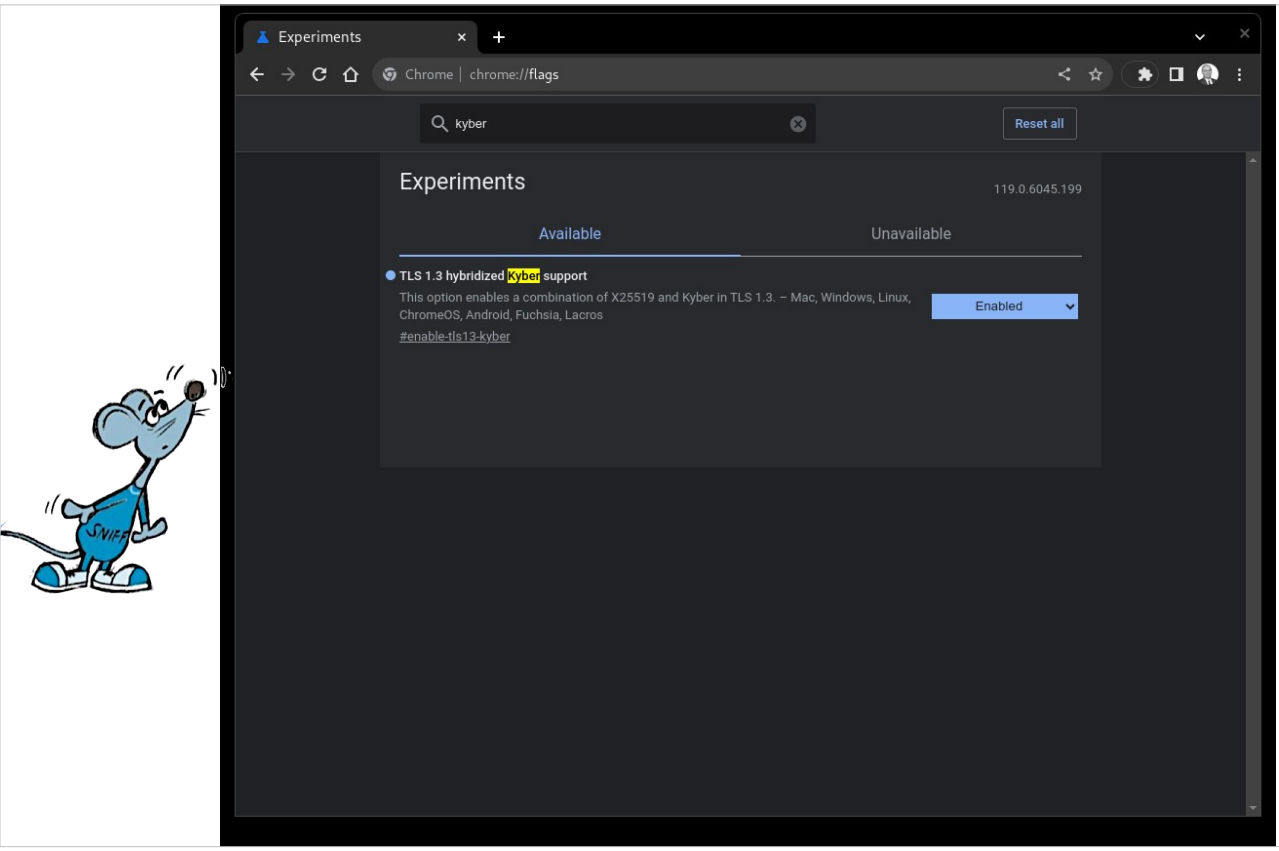


CRYSTALS-Kyber for example, uses techniques created in 2005 called Learning with Errors. Instead of being based on factoring semiprimes, discrete logarithms, or elliptic curves, it uses lattices and introduces errors to make discovery difficult mathematically, even for large scale quantum computers without interference issues.

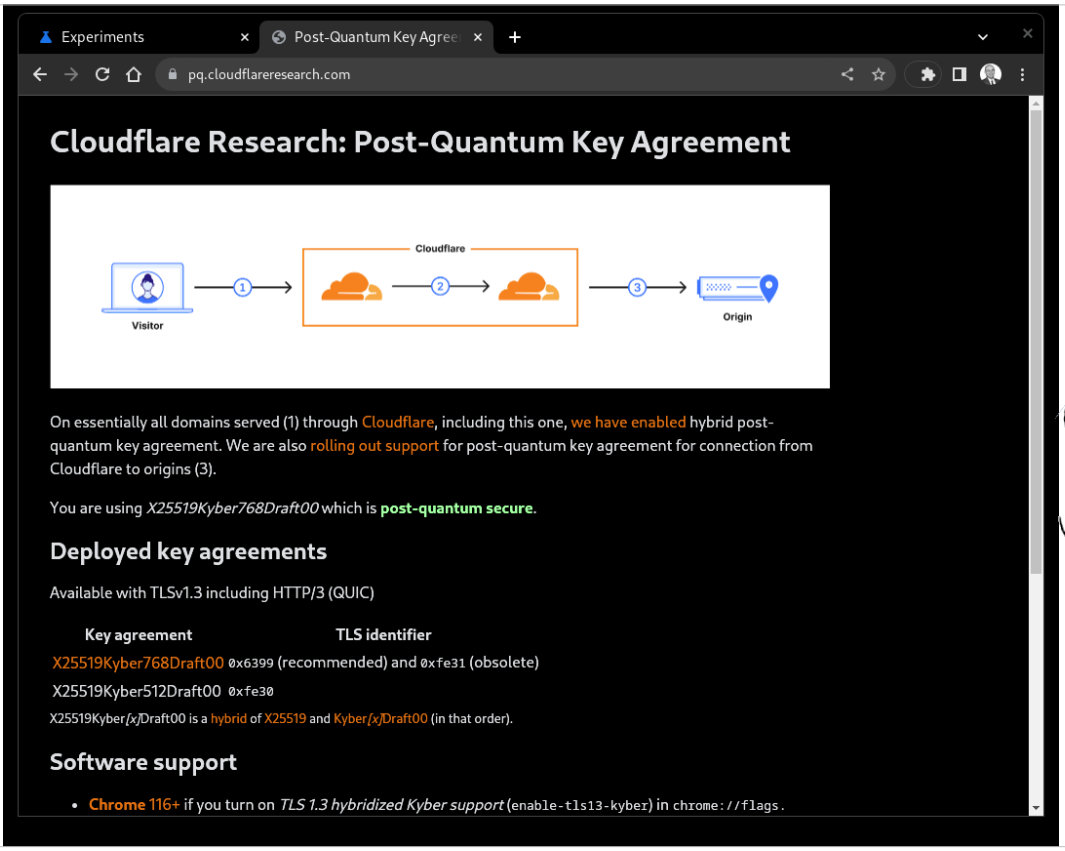
Post-Quantum Cryptography (PQC) - where are we?

- X25519MLKEM768 (formerly X25519Kyber768Draft00) readily available to test
  - Google Chrome
  - Firefox
  - BoringSSL
  - Nginx
- IAS - https://pqc.ias.edu (with presentation slides!)
- Cloudflare Research - https://pq.cloudflareresearch.com/
- Signal - https://signal.org/blog/pqxdh/
- Apple iMessage - https://security.apple.com/blog/imessage-pq3/

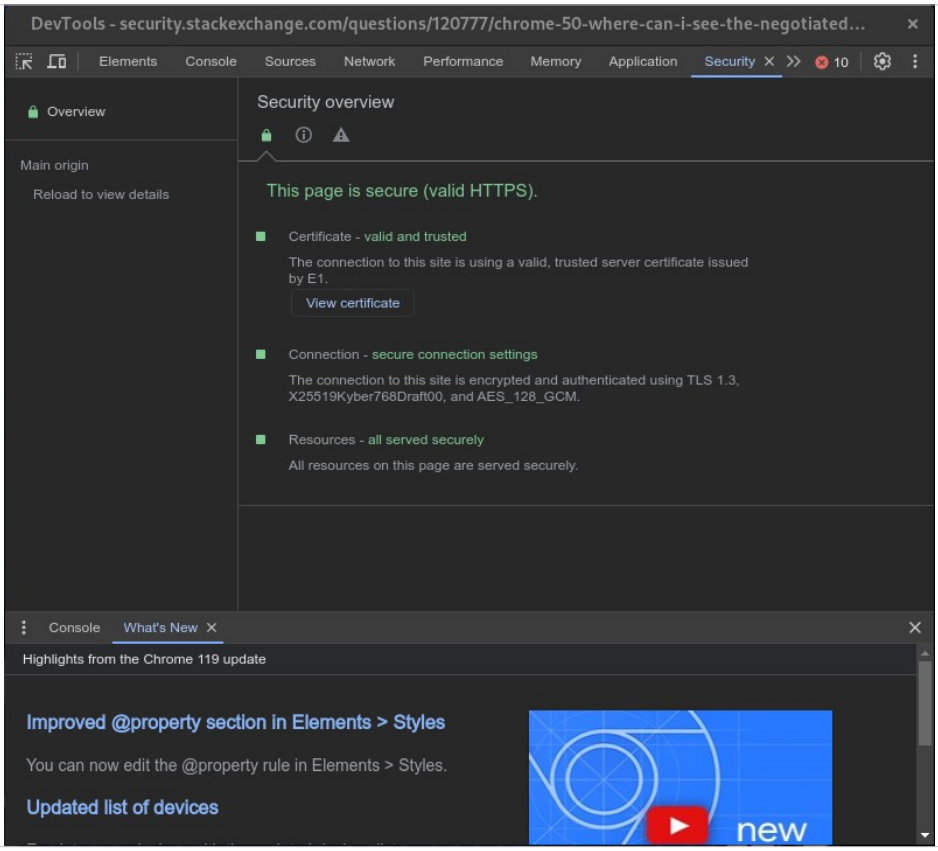
These algorithms have been <Click> encoded for use in various <Click> applications <Click> for <Click> testing <Click>. IAS <Click> opened its first PQC website today (2026-02-18) which has the slides for this presentation on it. It uses a standard RHEL10.1 server running stock OpenSSL and Apache with a commercial ECC certificate and hybrid authentication. And Cloudflare <Click> has released a tool <Click> where you can test. As mentioned before, Signal <Click> has adopted QSC, and so has <Click> Apple for its iMessage application.



Enabling Kyber support in the latest versions of Google Chrome (Microsoft Edge, Samsung Internet, Opera, Brave, etc), for example, is easy to do. As of August 2023, Google Chrome 124 enables X25519+Kyber by default.



Once enabled, you can test your browser against Cloudflare's test site. Quantum-Safe Cryptography is here!



Here we have Stack Exchange which is using Kyber as well! You can access developer tools via <F12> in chrome and then look at the security tab to see what cipher you are using.

Sadly, this information is not available via the Chrome extension API, so we won't get a nice extension to tell us if we are quantum safe or not. You'll have to use the developer's tools.

What do we need to do?

1. Don’t panic.
2. Educate yourself and your company on the risks.
3. Understand your environment.
    a. Where do you use encryption?
    b. What type of encryption do you use?
    c. Can you update? Are your vendors working on implementing PQC?
    d. Realize that you should be auditing your encryption usage anyway.

<Click> As with all things, don’t panic, and don’t let your company panic. Good leadership will show that calm, collective forward movement will prevail.
<Click> Educate yourself and your leadership on the risks you face. Make sure this is treated as a priority to plan for now. You have time, but don’t become complacent.
<Click> Start auditing your environment now to understand your exposure. <Click> You may be surprised to find out where you use encryption, <Click> and the type of encryption you use. Are your certificates already expired? <Click>Are you still using certificates with SHA-1 signatures. <Click>

Nothing on this list should be new to a seasoned IT professional. Technology changes all the time and we have to constantly balance upgrading and updating against risk and productivity.

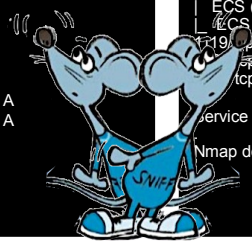
There are easy to use tools to scan your environment to see what cryptographic algorithms you are using and the health of your certificates.

```
[1]ep:~$ nmap -sV --script ssl-enum-ciphers --script ssl-cert www.example.com
Starting Nmap 7.93 ( https://nmap.org ) at 2023-12-12 20:54 EST
Nmap scan report for www.example.com (93.184.216.34)
Host is up (0.0055s latency).
Other addresses for www.example.com (not scanned):
2606:2800:220:1:248:1893:25c8:1946
Not shown: 995 filtered tcp ports (no-response)
PORT     STATE  SERVICE   VERSION
80/tcp   open   http      Edgecast CDN httpd (nyb/1DCD)
|_http-server-header: ECS (nyb/1DCD)
443/tcp  open   ssl/http  Edgecast CDN httpd (nyb/1DCD)
| ssl-enum-ciphers:
|   TLSv1.0:
|     ciphers:
|     compressors:
|       NULL
|     cipher preference: server
|   TLSv1.1:
|     ciphers:
|       TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA (secp256r1) - A
|       TLS_DHE_RSA_WITH_AES_128_CBC_SHA (dh 2048) - A
|       TLS_DHE_RSA_WITH_AES_256_CBC_SHA (dh 2048) - A
|       TLS_DHE_RSA_WITH_CAMELLIA_256_CBC_SHA (dh 2048) - A
|       TLS_DHE_RSA_WITH_CAMELLIA_128_CBC_SHA (dh 2048) - A
|       TLS_RSA_WITH_AES_256_CBC_SHA (rsa 2048) - A
|       TLS_RSA_WITH_CAMELLIA_256_CBC_SHA (rsa 2048) - A
|       TLS_DHE_RSA_WITH_SEED_CBC_SHA (dh 2048) - A
|     compressors:
|       NULL
|     cipher preference: server
|   TLSv1.2:
|     ciphers:
|       TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256 (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384 (secp256r1) - A
|       TLS_DHE_RSA_WITH_AES_128_GCM_SHA256 (dh 2048) - A
|       TLS_DHE_RSA_WITH_AES_256_GCM_SHA384 (dh 2048) - A
|       TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA256 (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA384 (secp256r1) - A
|       TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA (secp256r1) - A
|     compressors:
|       NULL
|     cipher preference: server

|   TLSv1.3:
|     ciphers:
|       TLS_AKE_WITH_AES_256_GCM_SHA384 (secp256r1) - A
|       TLS_AKE_WITH_CHACHA20_POLY1305_SHA256 (secp256r1) - A
|       TLS_AKE_WITH_AES_128_GCM_SHA256 (secp256r1) - A
|     cipher preference: server
|_  least strength: A
| ssl-cert: Subject: commonName=www.example.org/organizationName=Internet\xC2\
xA0Corporation\xC2\xA0for\xC2\xA0Assigned\xC2\xA0Names\xC2\xA0and\xC2\
xA0Numbers/stateOrProvinceName=California/countryName=US
| Subject Alternative Name: DNS:www.example.org, DNS:example.net, DNS:example.edu
DNS:example.com, DNS:example.org, DNS:www.example.com, DNS:www.example.edu,
DNS:www.example.net
| Issuer: commonName=DigiCert TLS RSA SHA256 2020 CA1/organizationName=DigiCe
Inc/countryName=US
| Public Key type: rsa
| Public Key bits: 2048
| Signature Algorithm: sha256WithRSAEncryption
| Not valid before: 2023-01-13T00:00:00
| Not valid after:  2024-02-13T23:59:59
| MD5:   749bbbeb4a6cb23c205c9850b35bed6a
|_SHA-1: f2aad73d32683b716d2a7d61b51c6d5764ab3899
| http-server-header:
|   ECS (nyb/1D2E)
|_  ECS (nyb/1DCD)
[19   closed bnetgame
      p open   h323q931?
      tcp closed rtmp

ervice detection performed. Please report any incorrect results at https://nmap.org/submi

Nmap done: 1 IP address (1 host up) scanned in 189.80 seconds
```



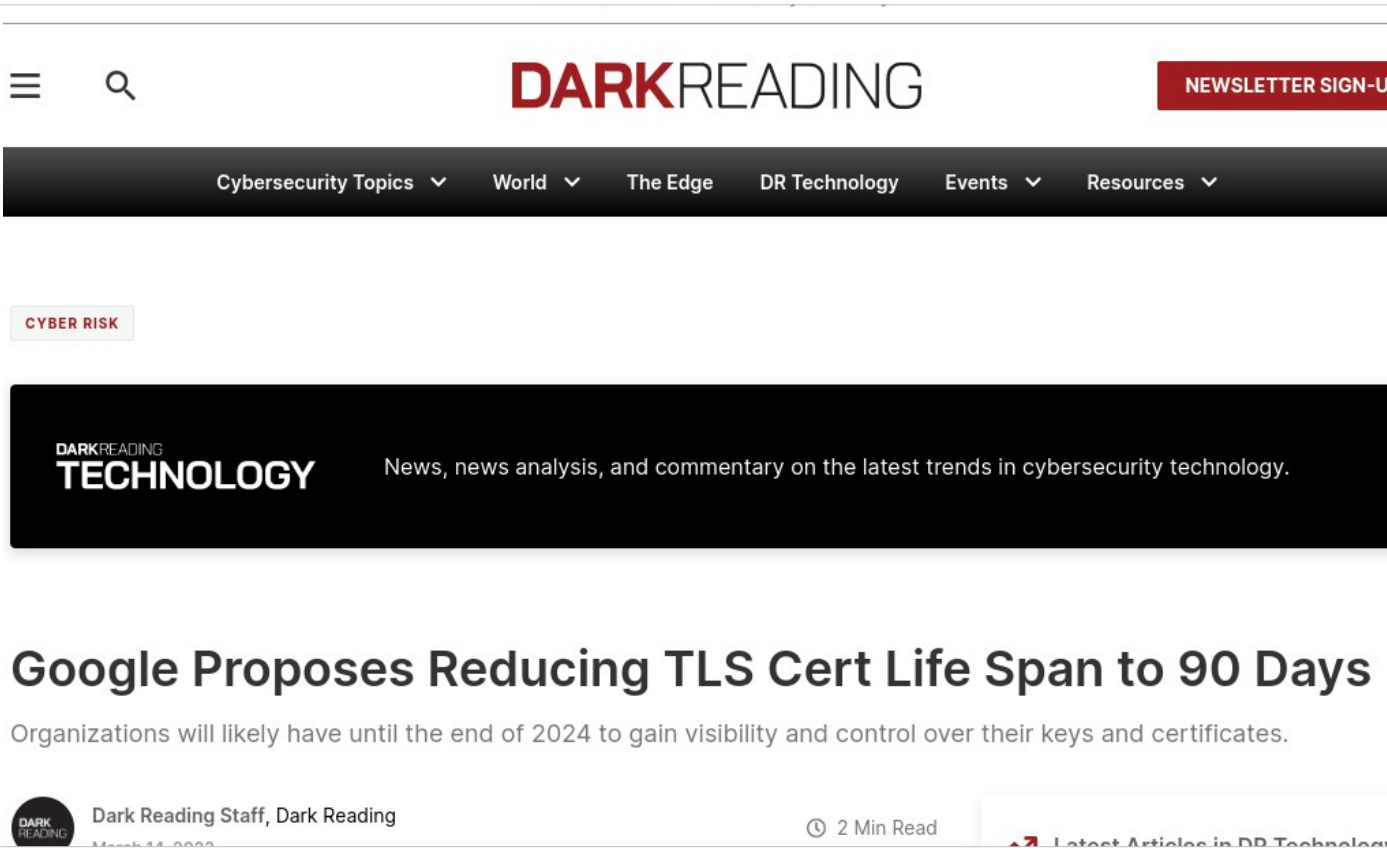
Here is an example of a simple scan of a host with the free open source tool, nmap. You can easily expand this to your entire environment and the script automatically scans around 1000 known ports that serve TLS and STARTTLS. It supports the majority of protocols, too.

What do we need to do?

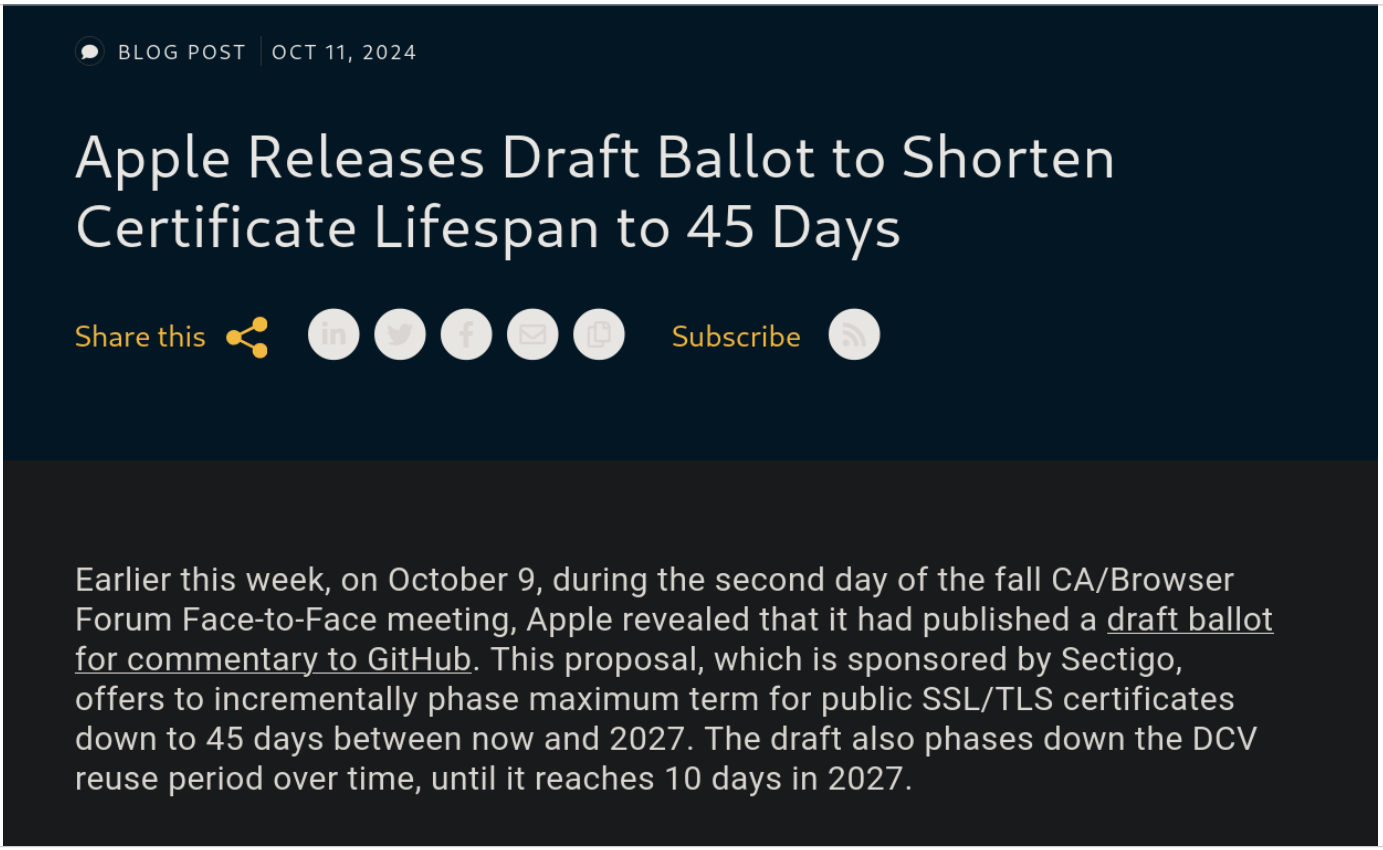
1. Plan
    a. What can you upgrade?
    b. What can't you upgrade?
    c. Risk Analysis
2. Execute your Plan
3. Automation
    a. ACME - Automatic Certificate Management Environment
    b. SCEP - Simple Certificate Enrollment Protocol
    c. REST/API - Check with your certificate provider, InCommon supports this

Based on your encryption audit, <Click>make a plan. Find out <Click> what can be upgraded, and <Click> what can't. Do a <Click> risk analysis of the things that are too old to be updated, or just can't. Do you have a replacement plan for those items? <Click> then execute your plan when the technology becomes available.

<Click> Also, remember that automation for certificate deployment is important to consider. Chromium, the backend engine to most modern browsers (with the notable exception of Firefox) is proposing to reduce TLS Cert Life Span from 398 days to 90 days. This means you'll have to replace your certs every 90 days.



Being able to deploy these in a large environment will really need to rely on automation. Setting this up now will mean it is all that much easier to deploy PQC when it is made available.



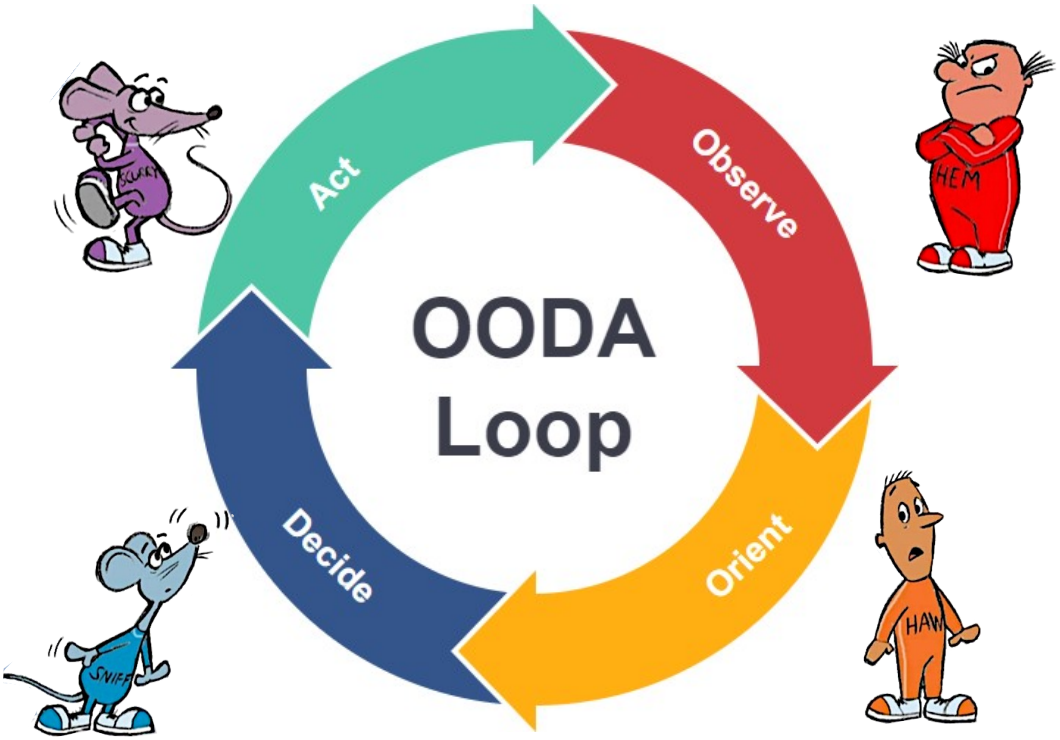
And of course, Apple had to one up Google on this one.

Although no official timeline has been released, it has been suggested that they may push this change before the end of 2024. This is something that I'm worried about.

Module-Lattice-based Key-Encapsulation Mechanism FIPS-203

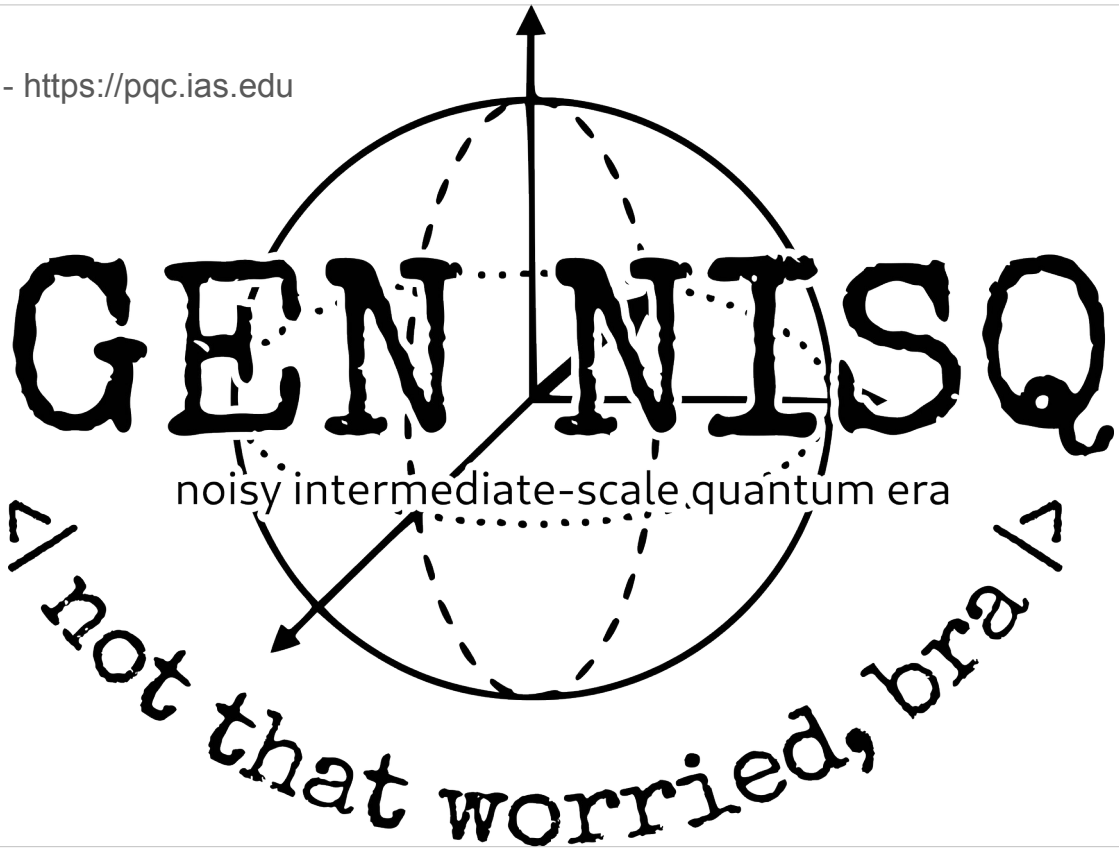
13. Qualifications. In applications, the security guarantees of a KEM only hold under certain conditions (see NIST SP 800-227 [1]). One such condition is the secrecy of several values, including the randomness used by the two parties, the decapsulation key, and the shared secret key itself. Users shall, therefore, guard against the disclosure of these values. While it is the intent of this standard to specify general requirements for implementing ML-KEM algorithms, **conformance to this standard does not ensure that a particular implementation is secure**. It is the responsibility of the implementer to ensure that any module that implements a key establishment capability is designed and built in a secure manner. Similarly, the use of a product containing an implementation that conforms to this standard does not guarantee security of the overall system in which the product is used. The responsible authority in each agency or department shall ensure that an overall implementation provides an acceptable level of security. NIST will continue to follow developments in the analysis of the ML-KEM algorithm. As with its other cryptographic algorithm standards, **NIST will formally reevaluate this standard every five years**. Both this standard and possible threats that reduce the security provided through the use of this standard will undergo review by NIST as appropriate, taking into account newly available analysis and technology. In addition, the awareness of **any breakthrough in technology or any mathematical weakness of the algorithm will cause NIST to reevaluate** this standard and provide necessary revisions.

And remember, we are all in this boat together. NIST describes Module-Lattice-based Key-Encapsulation Mechanism in FIPS-203. Note that NIST already plans to re-evalutate the protocol every 5 years or if needed sooner. Once again, repeating the cyclical nature of information security



The OODA loop (observe, orient, decide, act) was developed by military strategist and United States Air Force Colonel John Boyd. Remaining agile and following the steps of Observe <Click>, Orient <Click>, Decide <Click>, and Act <Click> will keep us always moving in the right direction.

Slides - https://pqc.ias.edu



Thank you!