USC CSci530
Computer Security Systems
Lecture notes Fall 2021

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This file will be updated to include future lectures through mid-term

CSci530: Security Systems

Lecture 1 – August 27, 2021 – OHE122

The Security Problem

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http://ccss.usc.edu/530

Administration

- Class home page

  http://ccss.usc.edu/530

  (redirect broken, so for now)

  http://www.csclass.info/USC/CSCI530/F21/

  – Preliminary Syllabus
  – Assigned Readings
  – Lecture notes
  – Assignments

Who gets in

- If you wish to enroll and do not have D clearance yet, send an email to CSci530@usc.edu with:
  - Your name
  - If you meet the prerequisites
  - A phone number
  - Request to received D clearance
- I will assess and approve if appropriate.

Structure of lecture

- Classes from 9:00 AM – 11:50 AM
  - 10 minute break halfway through
  - Before or after break, 10 minutes for discussion of two current events, to be led by students.
    - Groups of 1 to 3. Send two sentences on topic by Wed, selected Thu AM then prepare slides.

Administration

- Lab Component (see http://ccss.usc.edu/530L)
  - 1 of the 4 units
  - Instruction 4:30-5:20 Fridays
    - This is not when you perform the labs
    - We may shift this instruction component online
    - Today's Lab instruction is introduction to the labs
  - You will perform the lab online during the following week
  - This semester,
    - All labs will be done remotely using DETER
    - You do the labs during the week that follows the "lab instruction"

Administration

- Class e-mail: csci530@usc.edu
- Instructor
  - Dr. Clifford Neuman – bcn@isi.edu
    - Please be sure to include CSCI530 in the subject of the message
  - Office hours Monday 12:30PM to 2:00 PM
    - Via Zoom – link to be emailed to class
  - Contact info on class web page
- TA
  - Not yet assigned

Administration

- Grading Base Grade
  - Reading reports: 5%,5%,5%
  - Exams: 25%, 30%
  - Research paper 30%
- Supplemental grade (can raise or lower base):
  - Lab exercises Pass(hi,lo)/Fail (adj 15%)
  - Class participation
    - up to 10% bonus

Desire 2 Learn

- Using the DEN Desire to Learn system
  - Follow Link to Lectures and Discussion forum from ccss.usc.edu/530 http://www.csclass.info/USC/CSCI530/F21/
  - Contact webclass@usc.edu if you have difficulty gaining access to the system.

Class Participation

- Class participation is important.
  - Ask and answering questions in class.
  - Ask, answer, participate on-line
  - Presentation of current events
- Bonus for class participation
  - If I don’t remember you from class, I look in the web discussion forum to check participation.
    - Did you ask good questions.
    - Did you provide good answers.
    - Did you make good points in discussions.

Academic Integrity

- I take Academic Integrity Seriously
  - Every year I have too many cases of cheating
  - Last year I assigned multiple F’s for the class
  - On occasion, students have been dismissed from program
- What is and is not OK
  - I encourage you to work with others to learn the material
  - Do not to turn in the work of others
  - Do not give others your work to use as their own
  - Do not plagiarize from others (published or not)
  - Do not try to deceive the instructors
- See section on web site and assignments
  - More guidelines on academic integrity
  - Links to university resources
  - Don’t just assume you know what is acceptable.

The Three Aspects of Security

- Confidentiality
  - Keep data out of the wrong hand
- Integrity
  - Keep data from being modified
- Availability
  - Keep the system running and reachable

Policy v. Mechanism

- **Security policy defines what is and is not allowed**
  - **What confidentiality, integrity, and availability actually mean**
- **Security mechanism is a method or tool for enforcing security policy**
  - Prevention
  - Detection
  - Reaction
- **Among mechanisms are:**
  - **Mechanisms enforce policy.**
  - Mechanisms may solve intermediate problems.
    - Authentication, Audit
    - Containment

Trusted vs. Trustworthy

- We trust our computers
  - We depend upon them.
  - We are vulnerable to breaches of security.
- Our computer systems today are not worthy of trust.
  - We have buggy software
  - We configure the systems incorrectly
  - Our user interfaces are ambiguous regarding the parts of the system with which we communicate.
- Trust is for a purpose and an assumed environment

Terminology

Trusted – Parts of a system that we depend upon for the proper enforcement of policies, whether or not the code is free of vulnerabilities (almost all systems have vulnerabilities). - as compared with

Trustworthy – our belief that a system is free of vulnerabilities that could result in the violation the relevant security policies.

Accreditation – A statement by a third party that a system or software has been found to be trustworthy with respect to a particular set of policies and for a particular operational environment.

Important Considerations

- Risk analysis and Risk Management
  - Impact of loss of data.
  - Impact of disclosure.
  - Legislation may play a role.

- Human factors
  - The weakest link

In The Shoes of an Attacker

- Motivation
  - Bragging Rights
  - Revenge / to inflict damage
  - Terrorism and Extortion
  - Financial / Criminal enterprises
  - Nation State Objectives

- Risk to the attacker
  - Can play a defensive role
  - Including effective attribution

Kinds of Adversaries: Users of Published Attack Tools

- Attacker has specific tools
  - Casts the tool widely to see what can be caught.
  - Sometimes described as script-kiddies
    - Gets them into systems or with specific vulnerabilities
    - Gets them account access to susceptible employees
  - The gather what they find, exfiltrate or modify, and stop there
- Strong security posture is effective
  - Sound security practices
  - Systems up to date
  - Least privilege

Kinds of Adversaries: Opportunistic or Bottom Up Adversaries

- Looks for the weak link
  - Uses tools to scan for vulnerabilities
  - Once in, repeats the process
    - This time starting with elevated access because of the system or user ID already compromised.
- Your containment architecture is critical against such adversaries.
  - You need to be aware of the paths that might be
    followed to reach sensitive data.

Kinds of Adversaries: Goal Oriented Top Down Adversaries

- Learns about your organization and system
  - Goal is to compromise some component of your system or access specific data.
  - Learns precursor activities that must be achieved to meet that goal.
  - Often applies APT – Advanced Persistent Threat tactics
  - Will wait for threat vector to propagate
- Defenses require all of:
  - Strong security posture
  - Training of privileged employees
  - Containment Architecture
  - Strong defenses to subversion.

Economics of Malicious Code

- Controlled machines for sale
- “Protection” or “recovery” for sale
- Attack software for sale
- Stolen data for sale
- Intermediaries used to convert online balances to cash.
  - These are the pawns and the ones that are most easily caught

Terminology (around attacks)

Vulnerability – A weakness in a system, program, procedure, or configuration that could allow an adversary to violate the intended policies of a system.

Threat – Tools or knowledge (capabilities) that care capable of exploiting a vulnerability to violate the intended policies of a system.

Attack – An attempt to exploit a vulnerability to violate the intended policies of a system.

Compromise or intrusion – The successful actions that violate the intended polices of a system.

Incidents and Breaches

Penetration – A successful attack (intrusion) that exploits a vulnerability in the code base of a system or its configuration. The result will often be to install a subversion.

Denial of Service – An attack that prevents authorized access to a resource, by destroying a target or overwhelming it with undesired requests.

Subversion - An intentional change to the code base or configuration of a system that alters the proper enforcement of policy. This includes the installation of backdoors and other control channels in violation of the policy relevant to the system.

Subversion vectors – the methods by which subversions are introduced into a system. Often the vectors take the form of malicious code.

More Terminology

Secure – A system is secure if it correctly enforces a correctly stated policy for a system. A system can only be secure with respect to a particular set of policies and under a set of stated assumptions. There is no system that is absolutely secure.

Trusted Computing Base – That part of a system which if compromised affects the security of the entire system. One often unstated assumption made with respect to a secure system is that the TCB is correctly implemented and has not been compromised.

Attack Surface – The accumulation of all parts of a system that are exposed to an adversary against which the adversary can try to find and exploit a vulnerability that will render the system insecure (i.e. violate the security policies of the system).

What is security

- System, Network, Data
  - What do we want to protect
  - From what perspective
- How to evaluate
  - Balance cost to protect against cost of compromise
  - Balance costs to compromise with risk and benefit to attacker.
- Security vs. Risk Management
  - Prevent successful attacks vs. mitigate consequences.
- It’s not all technical

Security and Society

- Does society set incentives for security.
  - OK for criminal aspects of security.
  - Not good in assessing responsibility for allowing attacks.
  - Privacy rules are a mess.
  - Incentives do not capture gray area
    - Spam and spyware
    - Tragedy of the commons

Why we aren’t secure

- Buggy code
- Protocols design failures
- Weak crypto
- Social engineering
- Insider threats
- Poor configuration
- Incorrect policy specification
- Stolen keys or identities
- Denial of service

What do we want from security

- Confidentiality
  - Prevent unauthorized disclosure
- Integrity
  - Authenticity of document
  - That it hasn’t changed
- Availability
  - That the system continues to operate
  - That the system and data is reachable and readable.
- Enforcement of policies
  - Privacy
  - Accountability and audit
  - Payment

The role of policy in security architecture

Policy – Defines what is allowed and how the system and security mechanisms should act.

Enforced By

Mechanism – Provides protection
interprets/evaluates
(firewalls, ID, access control, confidentiality, integrity)

Implemented as:

Software: which must be implemented correctly and according to sound software engineering principles.

Security Mechanisms

- Encryption
- Checksums
- Key management
- Authentication
- Authorization
- Accounting
- Firewalls
- Virtual Private Nets
- Intrusion detection
- Intrusion response
- Development tools
- Virus Scanners
- Policy managers
- Trusted hardware

Today’s security deployment

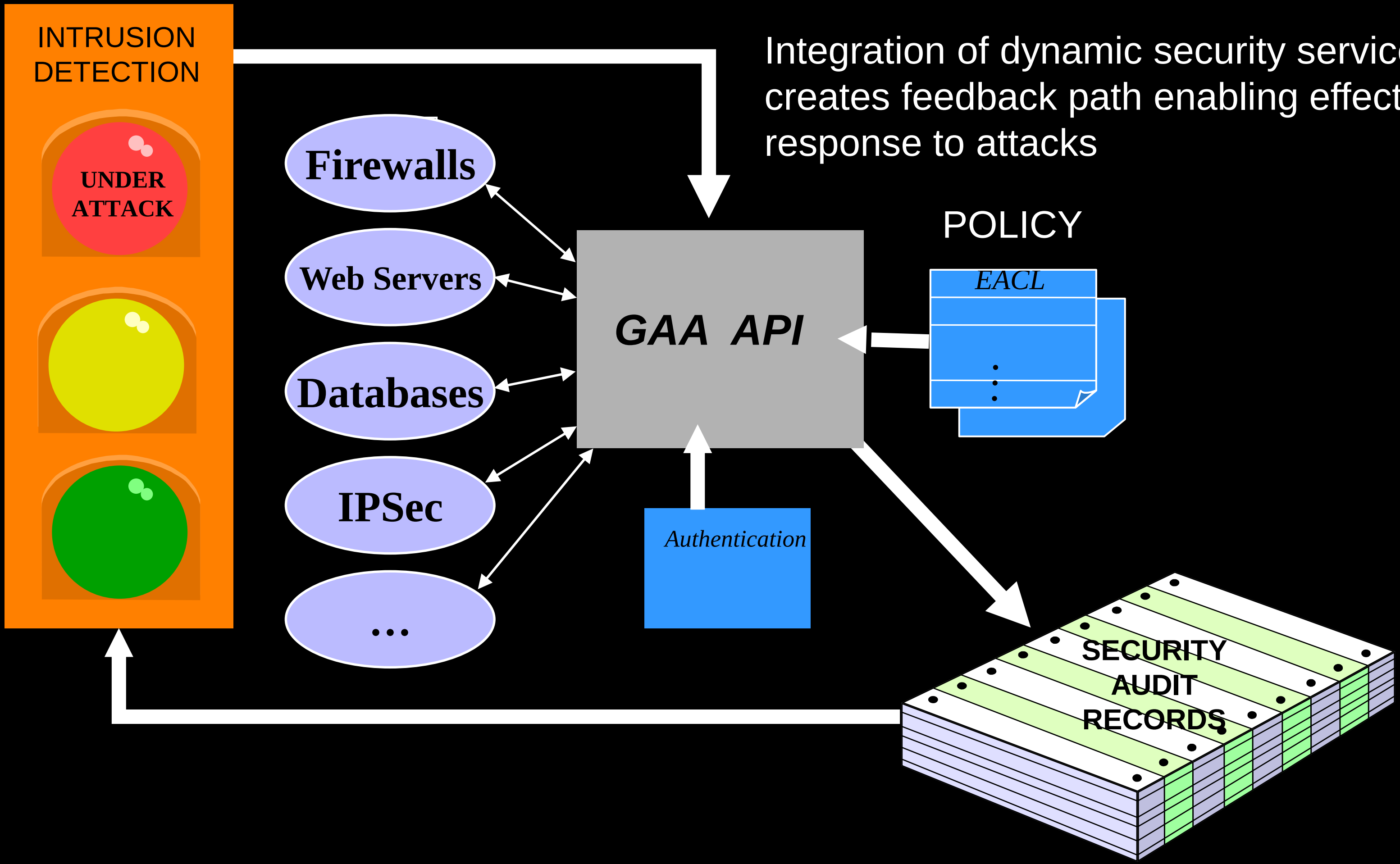
- Most deployment of security services today handles the easy stuff, implementing security at a single point in the network, or at a single layer in the protocol stack:
  - Firewalls, VPN’s
  - IPSec
  - SSL
  - Virus scanners
  - Intrusion detection

A more difficult problem

- **Unfortunately, security isn’t that easy. It** must **be better integrated with the application.**
  - **At the level at which it must ultimately be specified, security policies pertain to application level objects, and identify application level entities (users).**

Security Systems vs Systems Security

Integration of dynamic security services creates feedback path enabling effective response to attacks



Loosely Managed Systems

- Security is made even more difficult to implement since today’s systems lack a central point of control.
  - Home machines unmanaged
  - Networks managed by different organizations.
  - A single function touches machines managed by different parties.
    - Clouds
  - Who is in control?

Who is in Control

- The Intruder?
- The Government?
- Your employer?
- Those with whom you do business?
- Infrastrcture (cloud) providers?
- Ultimately, it must be you who takes control, but today’s systems don’t take that view.
  - You must balance conflicting interests and control.

Loosely Managed Systems (wrapping up since last week)

- Security is made even more difficult to implement since today's systems lack a central point of control.
  - Home machines unmanaged
  - Networks managed by different organizations.
  - A single function touches machines managed by different parties.
    - Clouds
  - Who is in control?

- End of Lecture 1

- Following slides are start of lecture 2

CSci530: Security Systems

Lecture 2 – September 3rd, 2021

Cryptography

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http://ccss.usc.edu/530

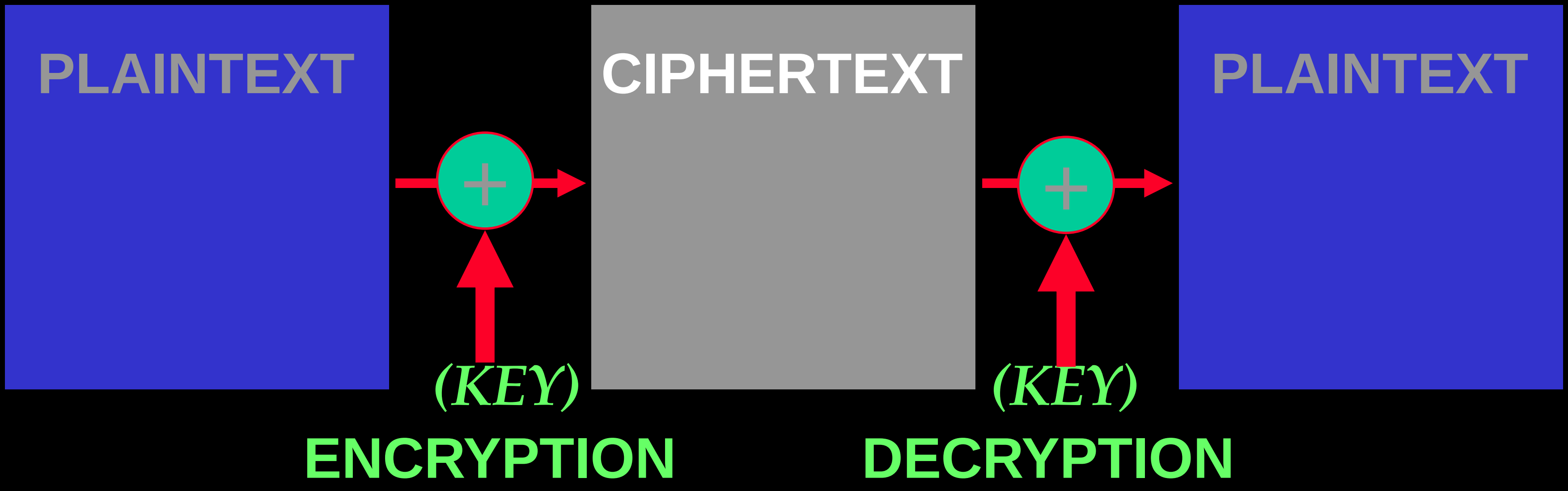
Cryptography and Security

- Cryptography underlies many fundamental security services
  - Confidentiality
  - Data integrity
  - Authentication
- It is a basic foundation of much of security.

A Brief History

- Steganography: “covered writing”
  - Demaratus and wax tablets
  - German microdots (WWII) .
  - Flaw: Discovery yields knowledge
    - Confidentiality through obscurity
- Cryptography: “secret writing”
  - TASOIINRNPSTO and TVCTUJUVUJPO

Encryption used to scramble data



The Basics of Cryptography

- Two basic types of cryptography
  - TASONO PINSTIR
    - Message broken up into units
    - Units permuted in a seemingly random but reversible manner
    - Difficult to make it easily reversible only by intended receiver
    - Exhibits same first-order statistics

The Basics of Cryptography

- Two basic types of cryptography
  - TRANSPOSITION (TASONOPINSTIR)
    - Message broken up into units
    - Units permuted in a seemingly random but reversible manner
    - Difficult to make it easily reversible only by intended receiver
    - Exhibits same first-order statistics

The Basics (continued)

- Two basic types of cryptography (cont)
  - TVCTUJUVUJPO
    - Message broken up into units
    - Units mapped into ciphertext
      - Ex: Caesar cipher
    - First-order statistics are isomorphic in simplest cases
    - Predominant form of encryption

The Basics (continued)

- Two basic types of cryptography (cont)
  - Substitution (TVCTUJUVUJPO)
    - Message broken up into units
    - Units mapped into ciphertext
      - Ex: Caesar cipher
    - First-order statistics are isomorphic in simplest cases
    - Predominant form of encryption

How Much Security?

- Mono-alphabetic substitution cipher
  - Permutation on message units—letters
    - 26! different permutations
    - Each permutation considered a *key*
  - Key space contains 26! = $4x10^{26}$ keys
    - Equals number of atoms in gallon H_2O
    - Equivalent to a 88-bit key

How Much Security?

- So why not use substitution ciphers?
  - Hard to remember 26-letter keys
    - But we can restrict ourselves to shorter keys
    - Ex: JULISCAERBDFGHKM, etc
  - Remember: first-order statistics are isomorphic
    - Vulnerable to simple cryptanalysis
    - Hard-to-read fonts for crypto?!

Crypto-analytic Attacks

- Classified as:
  - Cipher text only
    - Adversary sees only the ciphertext
  - Known plain text
    - May know some corresponding plaintext (e.g. Login:)
  - Chosen plaintext
    - Can ask to have text encrypted

Substitution Ciphers

- Two basic types
  - Symmetric-key (conventional)
    - Single key used for both encryption and decryption
    - Keys are typically short, because key space is densely filled
    - Ex: AES, DES, 3DES, RC4, Blowfish, IDEA, etc

Substitution Ciphers

- Two basic types (cont)
  - Public-key (asymmetric)
    - Two keys: one for encryption, one for decryption
    - Keys are typically long, because key space is sparsely filled
    - Ex: RSA, El Gamal, DSA, etc

One Time Pads

- For confidentiality, One Time Pad provably secure.
  - Generate truly random key stream size of data to be encrypted.
  - Encrypt: Xor plaintext with the keystream.
  - Decrypt: Xor again with keystream.
- Weak for integrity
  - 1 bit changed in cipher text causes corresponding bit to flip in plaintext.
- Key size makes key management difficult
  - If key reused, the cipher is broken.
  - If key pseudorandom, no longer provably secure
  - Beware of claims of small keys but as secure as one time pad – such claims are wrong.

Block vs. Stream: Block

- Block ciphers encrypt message in units called blocks
  - E.g. DES: 8-byte key (56 key bits), 8-byte block
  - AES (discussed later) is also a block cipher.
  - Larger blocks make simple cryptanalysis useless (at least for short messages)
    - Not enough samples for valid statistics
    - 8 byte blocks common
    - But can still tell if something is the same.

Key and Block Size

- Do larger keys make sense for an 8-byte block?
  - 3DES: Key is 112 or 168 bits, but block is still 8 bytes long (64 bits)
  - Key space is larger than block space
  - But how large is permutation space?

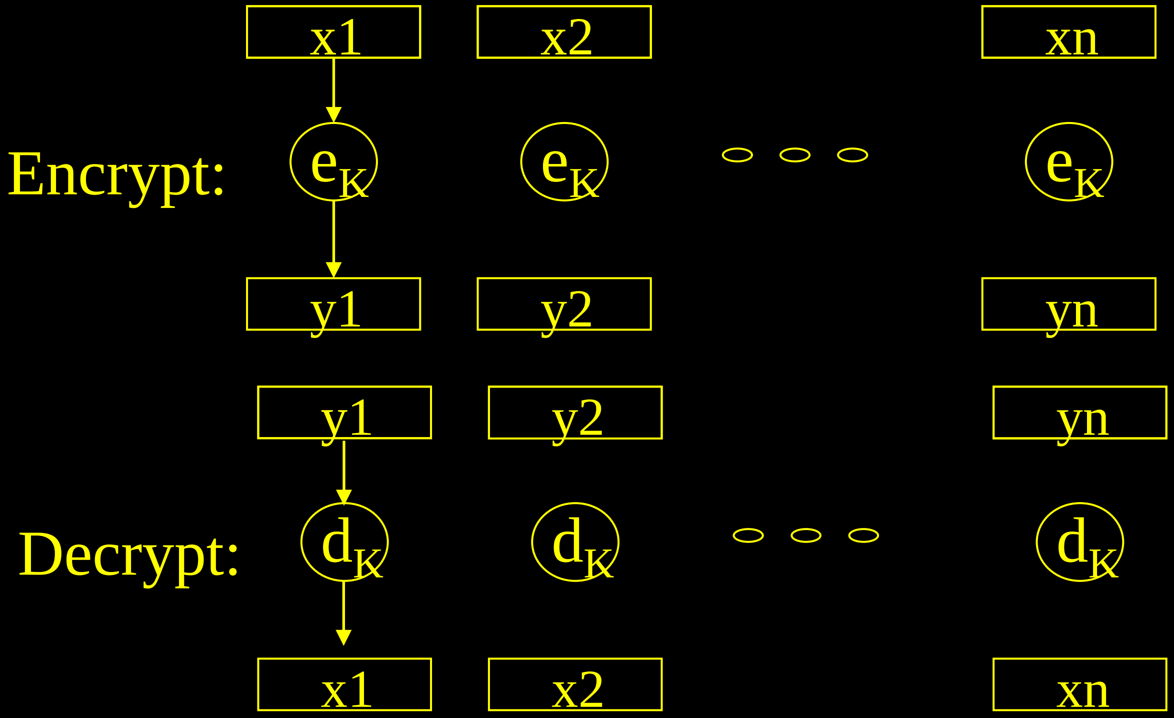
More on DES Internals

- More details on the internal operation of DES is covered in CSci531.
- But we cover Modes of Operation in this lecture since these modes are important to apply DES, and the same modes can be used for other block ciphers.

Block vs. Stream: Stream

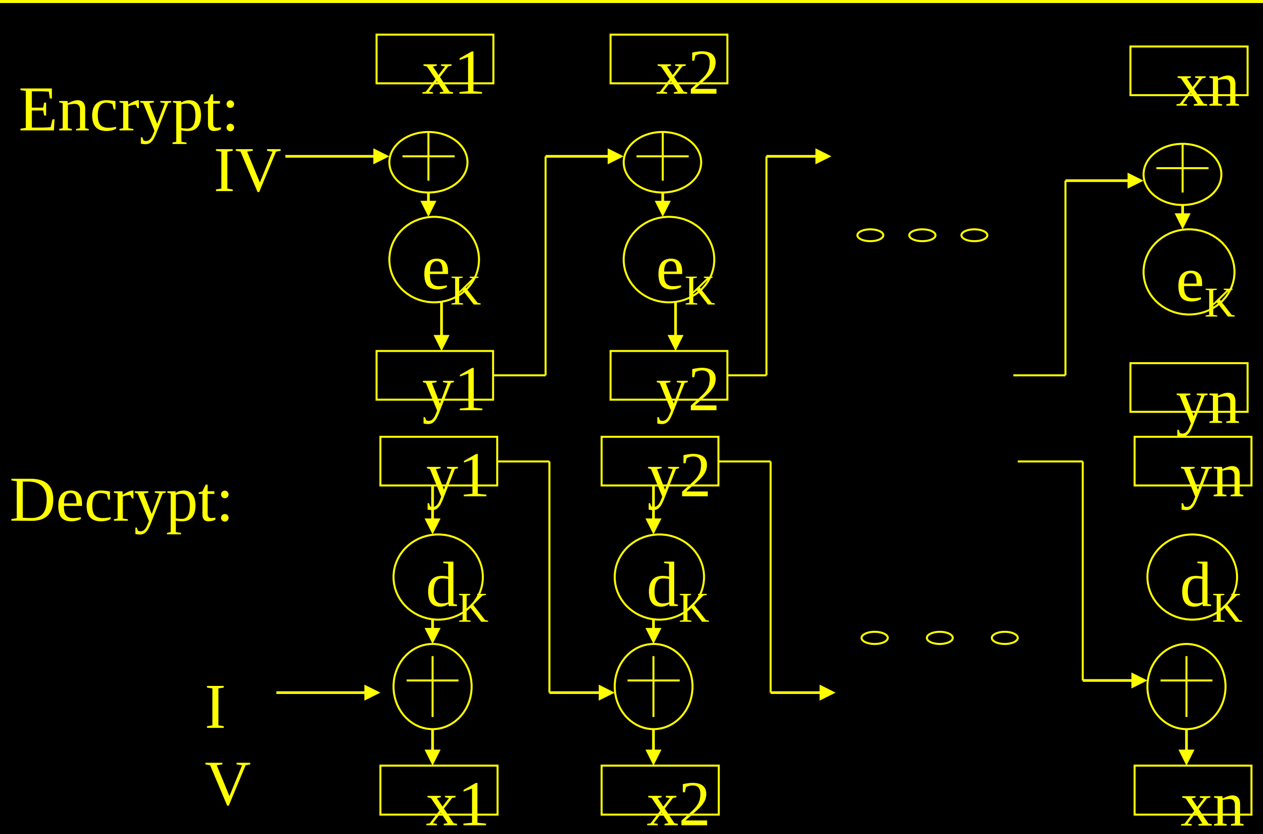
- Stream ciphers encrypt a bit, byte, or block at a time, but the transformation that is performed on a bit, byte, or block varies depending on position in the input stream and possibly the earlier blocks in the stream.
  - Identical plaintext block will yield a different cipher text block.
  - Makes cryptanalysis more difficult.
  - DES modes CBC, CFB, and OFB modes (discussed next) create stream ciphers from DES, which is a block cipher.
  - Similar modes available for AES.

DES Modes of Operation – Electronic Code Book (ECB)



- **Each block encrypted in isolation**
- **Vulnerable to block replay**

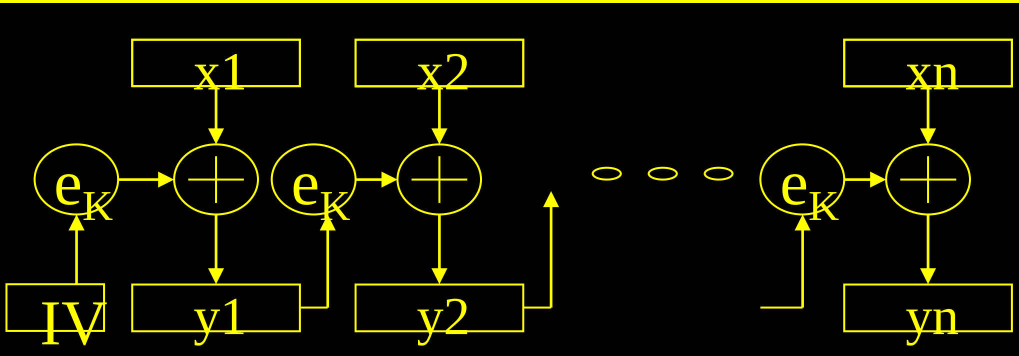
DES Modes of Operation – Cipher Block Chaining (CBC)



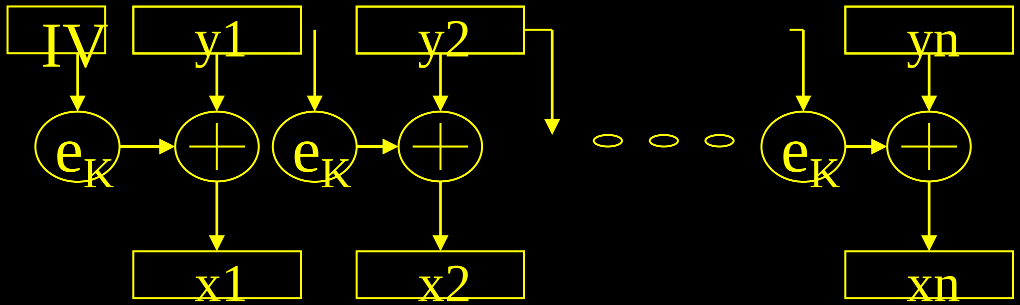
- Each plaintext block XOR’d with previous ciphertext
- Easily incorporated into decryption
- What if prefix is always the same? IV!

DES Modes of Operation – Cipher Feedback Mode (CFB)

Encrypt:

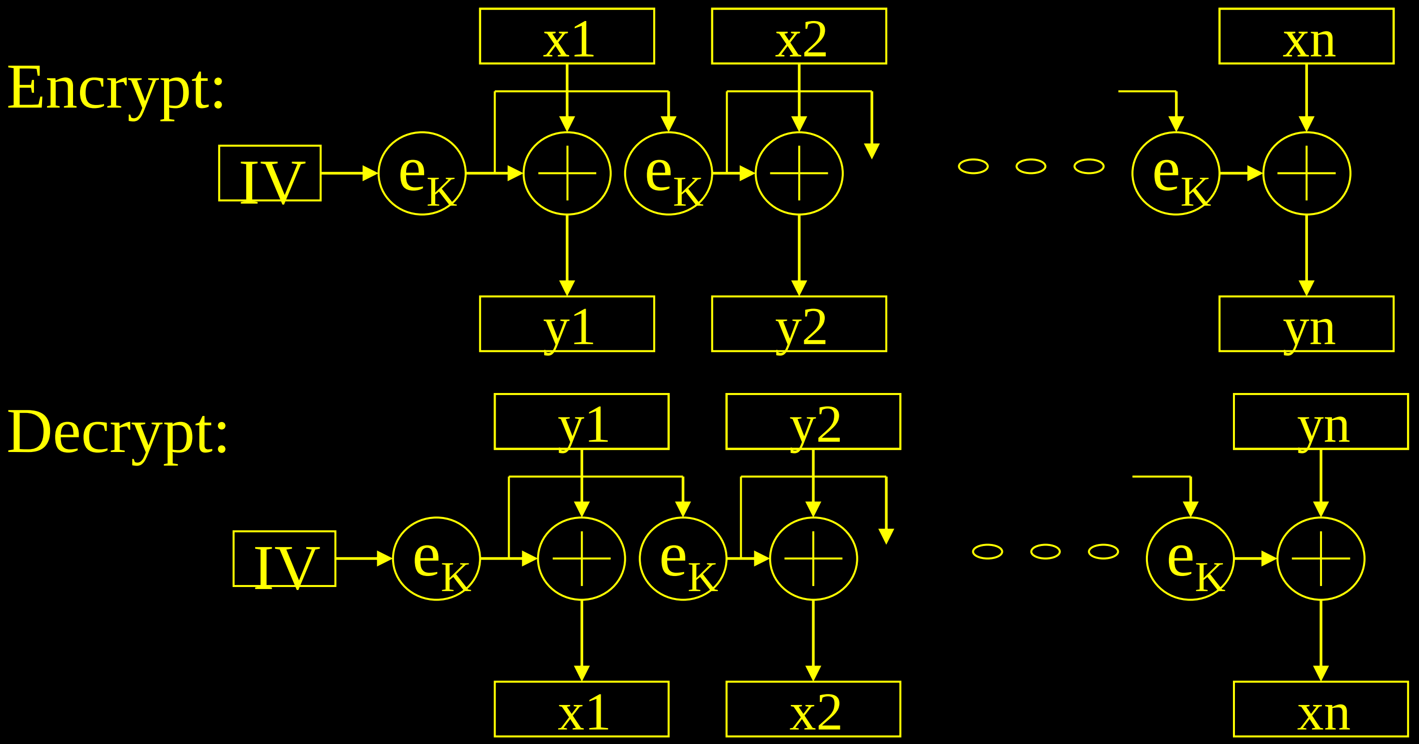


Decrypt:



- – **For encrypting character-at-a-time (or less)**
- – **Chains as in CBC**
- – **Also needs an IV – Must be Unique – Why?**

DES Modes of Operation – Output Feedback Mode (OFB)



– Like CFB, but neither ciphertext nor plaintext is fed back to the input of the block encryption.

CSci530: Security Systems

Lecture 3 – September 10, 2021 – OHE122

Cryptography (continued) then Key Management

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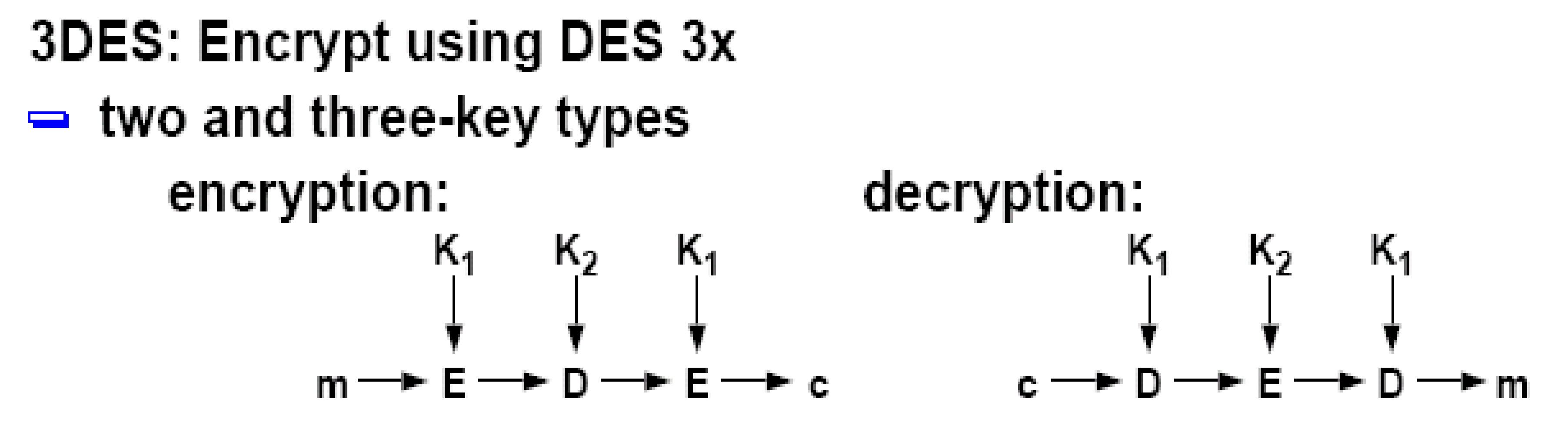
Variants and Applications

- 3DES: Encrypt using DES 3x
  - Two and three-key types
  - Inner and outer-CBC modes
- Crypt: Unix hash function for passwords
  - Uses variable expansion permutations
- DES with key-dependent S-boxes
  - Harder to analyze

3DES Using Two Keys



3DES: Encrypt using DES 3x

- two and three-key types

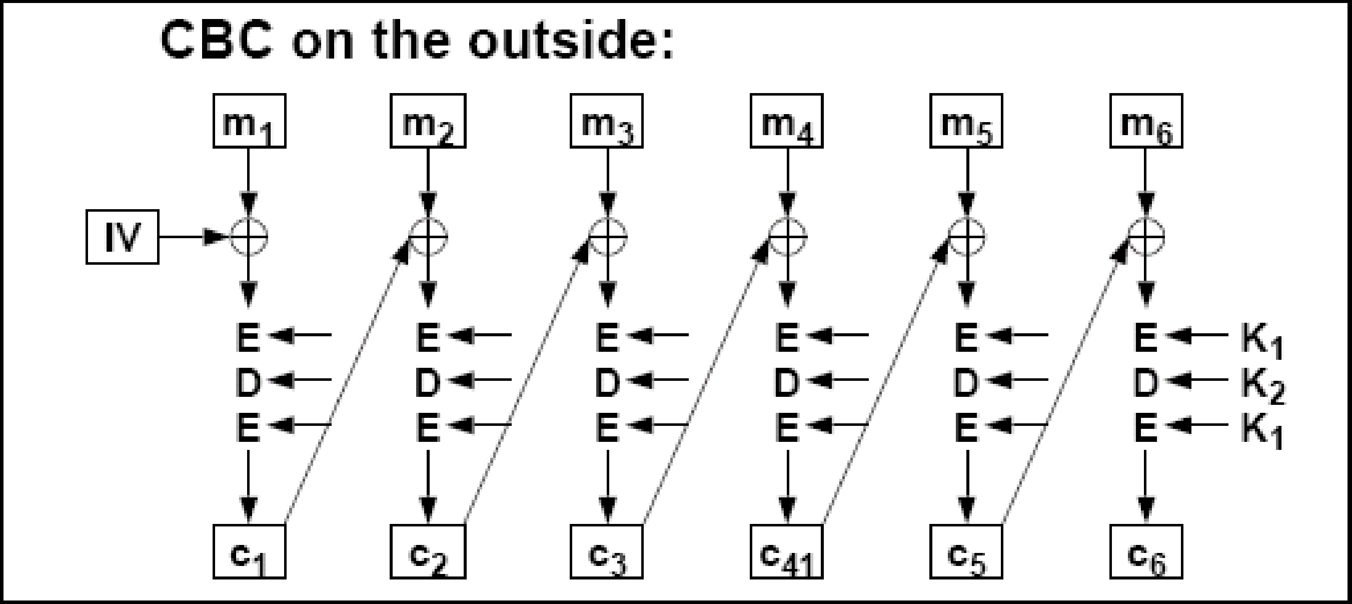
encryption:

decryption:

- Can use K1,K2,K3, or K1,K2,K1, or K1,K1,K1

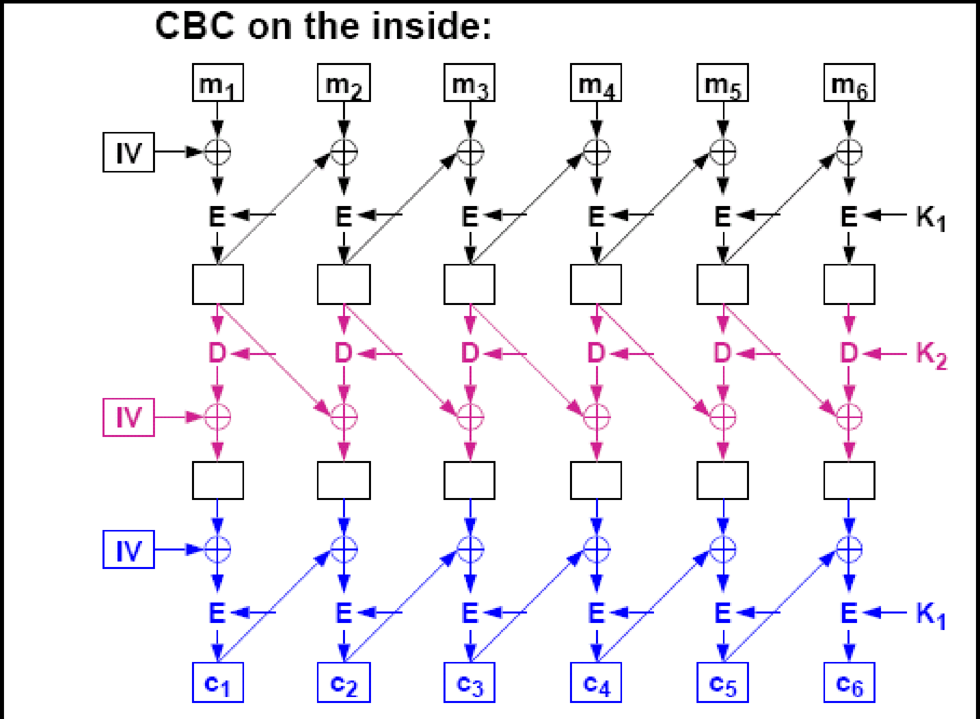
- Figure courtesy William Cheng

3DES Outer CBC



- Figure courtesy William Cheng

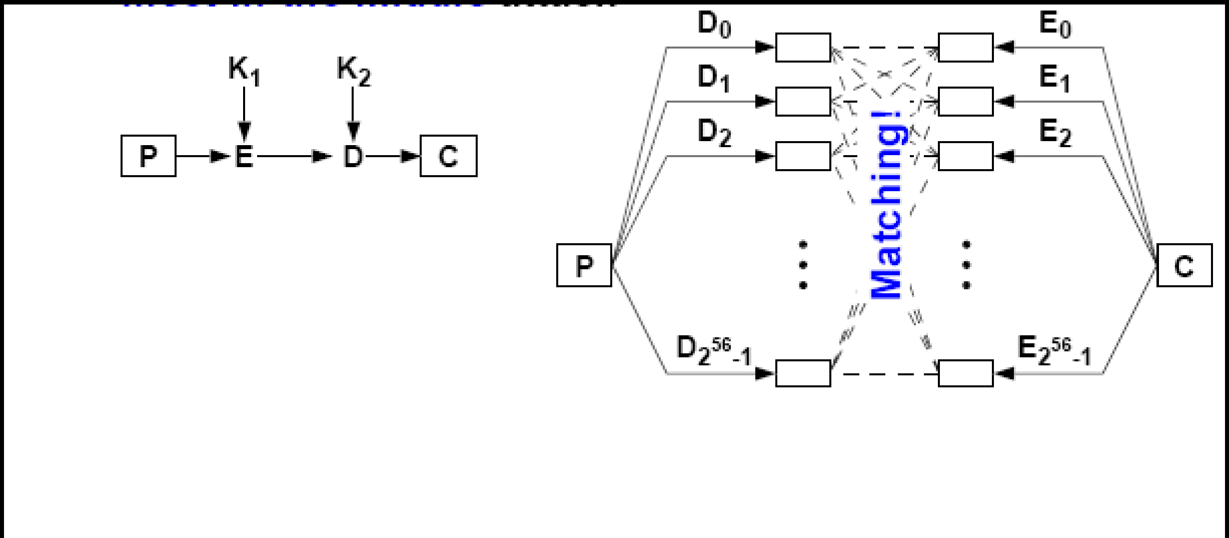
3DES Inner CBC



- Inner is more efficient, but less secure
  - More efficient due to ability to pipeline implementation
  - Weaker for many kinds of attacks

- Figure courtesy William Cheng

Why not Two Round



- Meet in middle attack makes it not much better than single DES.

- Figure courtesy William Cheng

Certification of DES

- Had to be recertified every ~5 years
  - 1983: Recertified routinely
  - 1987: Recertified after NSA tried to promote secret replacement algorithms
    - Withdrawal would mean lack of protection
    - Lots of systems then using DES
  - 1993: Recertified after continued lack of alternative

Enter AES

- 1998: NIST finally refuses to recertify DES
  - 1997: Call for candidates for Advanced Encryption Standard (AES)
  - Fifteen candidates whittled down to five
  - Criteria: Security, but also efficiency
    - Compare Rijndael with Serpent
    - 9/11/13 rounds vs 32 (breakable at 7)
  - 2000: Rijndael selected as AES

Structure of Rijndael

- Unlike DES, operates on whole bytes for efficiency of software implementations
- Key sizes: 128/192/256 bits
- Variable rounds: 9/11/13 rounds
- More details on structure in the applied cryptography class.

Security of Rijndael

- Key size is enough
- Immune to linear or differential analysis
- But Rijndael is a very structured cipher
- Attack on Rijndael’s algebraic structure
    - Breaking can be modeled as equations

Impact of Attacks on Rijndael

- Currently of theoretical interest only
  - Reduces complexity of attack to about 2^{100}
  - Also applicable to Serpent
- Still, uncomfortably close to feasibility
  - DES is already insecure against brute force
  - Schneier (somewhat arbitrarily) sets limit at 2^{80}
- Certainly usable pending further results

Public Key Cryptography

- aka asymmetric cryptography
- Based on some NP-complete problem
  - Unique factorization
  - Discrete logarithms
    - For any b, n, y: Find x such that b^x mod n = y
- Modular arithmetic produces folding

A Short Note on Primes

- Why are public keys (and private keys) so large?
- What is the probability that some large number p is prime?
  - About 1 in 1/ln(p)
  - When p ~ 2^{512}, equals about 1 in 355
    - About 1 in 355^2 numbers ~ 2^{1024} is product of two primes (and therefore valid RSA modulo)

RSA

- Rivest, Shamir, Adleman
- Generate two primes: p, q
  - Let n = pq
  - Choose e, a small number, relatively prime to (p-1)(q-1)
  - Choose d such that ed = 1 mod (p-1)(q-1)
- Then, c = m^e mod n and m = c^d mod n

An Example

- Let $p = 5$, $q = 11$, $e = 3$
  - Then $n = 55$
  - $d = 27$, since $(3)(27) \bmod 40 = 1$
- If $m = 7$, then $c = 7^3 \bmod 55 = 343 \bmod 55 = 13$
- Then m should $= 13^{27} \bmod 55$

An Example

- Computing 13^{27} mod 55
  - 13^{1} mod 55 = 13, 13^{2} mod 55 = 4, 13^{4} mod 55 = 16, 13^{8} mod 55 = 36, 13^{16} mod 55 = 31
  - 13^{27} mod 55 = (13)(4)(36)(31) mod 55 = (1872 mod 55)(31) mod 55 = 62 mod 55 = 7 (check)

Other Public Cryptosystems

- ElGamal (signature, encryption)
  - Choose a prime p, a generator < p
  - Choose a random number x < p
  - Public key is g, p, and y = g^x mod p
  - Private key is x; to obtain from public key requires extracting discrete log
  - Mostly used for signatures

Other Public Cryptosystems

- Elliptic curve cryptosystems
  - $y^2 = x^3 + ax^2 + bx + c$
  - Continuous elliptic curves used in FLT proof
  - Discrete elliptic curves used to implement existing public-key systems
    - Allow for shorter keys and greater efficiency

Importance of ECC

- There has been rapid progress in cryptanalysis of RSA and Diffie-Hellman public key systems.
  - http://www.technewsdaily.com/18662-internet-security-cryptopalypse.html
- ECC is based on different mathematics, which has been shown to be NP complete.

Hash Functions

- Given m, compute H(m)
- Should be…
  - Efficient: H() easy to compute
  - One-way: Given H(m), hard to find m’ such that H(m’) = H(m)
  - Collision-resistant: Hard to find m and m’ such that H(m’) = H(m)

Apple CSAM Detection using Cryptography

Josephine Hosner
Katie Foss
Prasoon Gautam

Overview and Technology Used

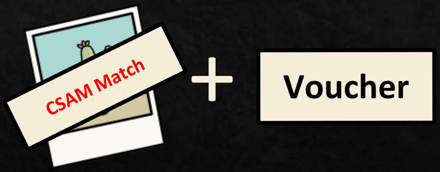
Purpose: "to help protect children from predators who use communication tools to recruit and exploit them, and limit the spread of Child Sexual Abuse Material (CSAM)." - Apple

Messages **CSAM Detection** **Siri and Search**

1 Private Set Intersection*

- Neural Hash
- Apple database resources from NCMEC and others

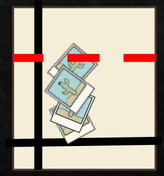
2 Cryptographic Safety Voucher*



- Voucher contains information about the match

3 Threshold Secret Sharing

- Content remains secret until an account passes the threshold



4 Taking Action

- Voucher analyzed by Apple
- Report to NCMEC
- Account disabled

0.00000000001

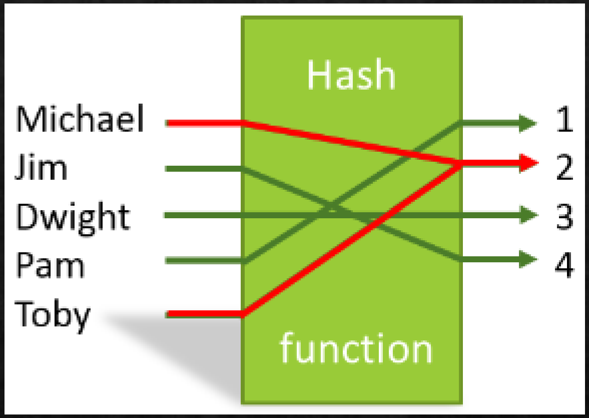
= probability of a false positive

*** = on user's device**

Implications

- How can this be used maliciously?
  - Framing
    - Purposeful hash collisions shared via Meme
  - Used by governments to target political dissent, other unlawful activity, etc.
- Public Opinion

As of September 3rd. "Based on feedback from customers, advocacy groups, researchers, and others, we have decided to take additional time over the coming months to collect input and make improvements before releasing these critically important child safety features."



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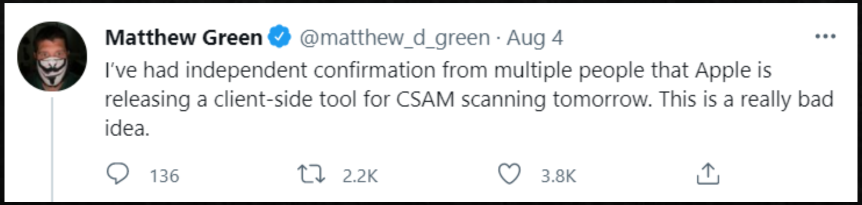

Matthew Green @matthew_d_green · Aug 4

I've had independent confirmation from multiple people that Apple is releasing a client-side tool for CSAM scanning tomorrow. This is a really bad idea.

Counter Measures

- No countermeasure as of now
- Disable photo backup to iCloud
- Will this help in the long run?
- Running locally so Apple has access to everything
- System non-bypassable

References

https://www.apple.com/child-safety/

https://www.apple.com/child-safety/pdf/Expanded_Protections_for_Children_Technology_Summary.pdf

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https://twitter.com/matthew_d_green/status/1423077918444507139

https://www.apple.com/child-safety/pdf/Expanded_Protections_for_Children_Frequently_Asked_Questions.pdf

Digital Signatures

- Provides data integrity
  - Can it be done with symmetric systems?
    - Verification requires shared key
    - Doesn’t provide non-repudiation
- Need proof of provenance
  - Hash the data, encrypt with *private* key
  - Verification uses public key to decrypt hash
  - Provides “non-repudiation”
    - But what does non-repudiation really mean?

Digital Signatures

- RSA can be used
- DSA: Digital Signature Algorithm
  - Variant of ElGamal signature
  - Adopted as part of DSS by NIST in 1994
  - Slower than RSA (but likely unimportant)
  - NSA had a hand in its design (?!)
  - Key size ranges from 512 to 1024 bits
  - Royalty-free

Cryptography in Use

- Provides foundation for security services
  - Provides confidentiality
  - Validates integrity
  - Provides data origin authentication
  - If we know the key
- Where does the key come from
  - Straightforward plan
    - One side generates key
    - Transmits key to other side
    - But how?

CSci530: Security Systems

Lecture 3 – September 10, 2021
Key Management

Dr. Clifford Neuman

University of Southern California

Information Sciences Institute

http://ccss.usc.edu/530

Key Management

- Key management is where much security weakness lies
  - Choosing keys
  - Storing keys
  - Communicating keys

What to do with keys

- Practical issues
  - How to carry them
    - Passwords vs. disks vs. smartcards
  - Where do they stay, where do they go
  - How many do you have
  - How do you get them to begin with.

Relevant News:
It is Easier to do it wrong

Internet of Sins: Million more devices sharing known private keys for HTTPS, SSH admin – The Register September 7, 2016.

Millions of internet-facing devices – from home broadband routers to industrial equipment – are still sharing well-known private keys for encrypting their communications.

This is according to research from SEC Consult, which said in a follow-up to its 2015 study on security in embedded systems that the practice of reusing widely known secrets is continuing unabated.

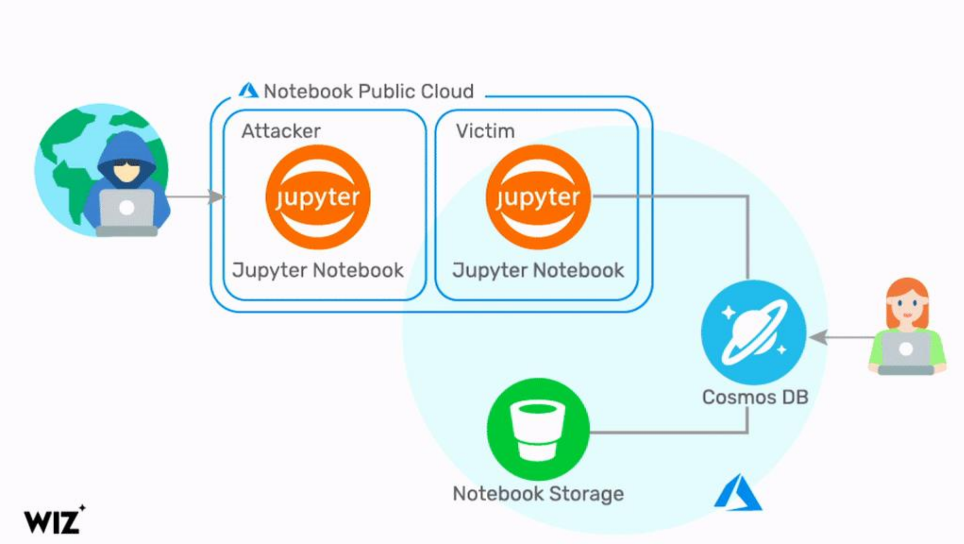
Devices and gadgets are still sharing private keys for their builtin HTTPS and SSH servers, basically. It is not difficult to extract these keys from the gizmos and use them to eavesdrop on encrypted connections and interfere with the equipment: imagine intercepting a connection to a web-based control panel, decrypting it, and altering the configuration settings on the fly. And because so many models and products are using the same keys, it's possible to attack thousands of boxes at once.

Microsoft Azure Data Breach

- “This is the worst cloud vulnerability you can imagine. It is a long-lasting secret.”
- “A critical security vulnerability in Microsoft’s Azure cloud database platform – CosmosDB – could have allowed full remote takeover of accounts, with admin rights to read write and delete any information to a database instance”

What Actually Happened ?

- This is done via Jupyter Notebook. A tool to visualize large amount of data.
- Wiz gained access to all the Primary keys and had access to R/W/D operations
- Wiz found a way to “ELEVATE” their privileges in their own Jupyter Notebook, which means now they could access ANY OTHER CosmosDB customer’s notebook.



Impact

- Microsoft claimed that there has not been any evidence that the vulnerability has been exploited; however, customers may still be impacted since their primary access keys were potentially exposed.

- Problems with Azure are especially troubling, because Microsoft and outside security experts have been pushing companies to abandon most of their own infrastructure and rely on the cloud for more security.

Countermeasures

- There are two main remediation steps:
  - Replace your Cosmos DBs' primary keys
  - Reduce network exposure of Cosmos DB accounts
- Before key regeneration they need to perform key rotation.
- To reduce network exposure, they can set Firewall rules that specify the exact addresses that may access your Cosmos DB accounts.

Long Term Goals

- The first and most important take away is that shared secrets such as ComosDB primary key are insecure and should be deprecated in favor of modern authentication methods.
- The longer-term goal should be to transition from these insecure primary/secondary keys to role-based access control (RBAC), which does not require any secrets at all.

Bootstrapping Security

- Exchange the key in person
  - Can exchange key before it is needed.
  - Could be a password.
- Hide the key in something else
  - Steganography, fairly weak
- Armored courier
  - If all else fails
- Send key over the net encrypted
  - But, using what key (bootstrap)

Diffie-Hellman Key Exchange (1)

- Choose large prime n, and generator g
  - For any b in (1, n-1), there exists an a such that $g^a = b$. This means that every number mod p can be written as a power of g (mod p).
    - To find such a g, pick the p such that p = 2q + 1 where q is also prime.
    - For such choices of p, half the numbers will be generators, and you can test if a candidate g is a generator by testing whether g^q (mod n) is equal to n-1.

Diffie-Hellman Key Exchange (2)

- Alice, Bob select secret values x, y
- Alice sends X = g^x mod n
- Bob sends Y = g^y mod n
- Both compute g^{xy} mod n,
  a shared secret
  - Can be used as keying material

Key Exchange (phrased differently)

- Diffie-Hellman key exchange
  - Choose large prime n, and generator g
    - For any b in (1, n-1), there exists an a such that $g^a = b$
  - Alice, Bob select secret values x, y, resp
  - Alice sends $X = g^x$ mod n
  - Bob sends $Y = g^y$ mod n
  - Both compute g^{xy} mod n, a shared secret
    - Can be used as keying material

Man in the middle of DH

- DH provides key exchange, but not authentication
  - You don’t really know you have a secure channel
- Man in the middle
  - You exchange a key with eavesdropper, who exchanges key with the person you think you are talking to.
  - Eavesdropper relays all messages, but observes or changes them in transit.
- Solutions:
  - Published public values
  - Authenticated DH (Sign or encrypt DH value)
  - Encrypt the DH exchange
  - Subsequently send hash of DH value, with secret

Two Cases so Far

- Can exchange a key with anyone, but you don’t know who you are talking with.
- Can exchange keys with known parties in advance, but are limited to communication with just those parties.

Peer-to-Peer Key Distribution

- Technically easy
  - Distribute keys in person
- But it doesn’t scale
  - Hundreds of servers…
  - Times thousands of users…
  - Yields ~ million keys

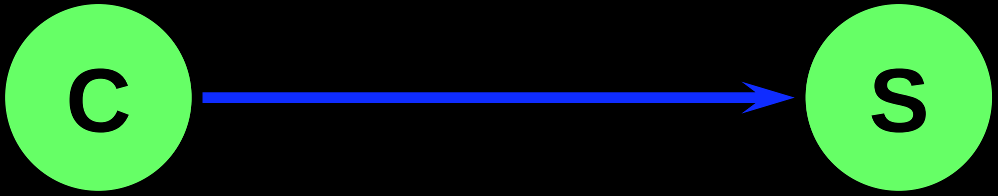
Incremental Key Distribution

- Build toward Needham-Schroeder and Kerberos mechanisms
- Key-distribution tied to authentication.
  - If you know who you share a key with, authentication is easy.
  - You want to know who has the key, not just that anyone has it.

But first a look forward – Encryption Based Authentication

- Proving knowledge of encryption key
  - Nonce = Non repeating value

{Nonce or timestamp}K_{CS}



But where does K_{cs} come from?

That is the subject of Key Distribution/Management

KDC Based Key Distribution

As used in both Needham Schroeder and Kerberos we will use Kerberos terminology

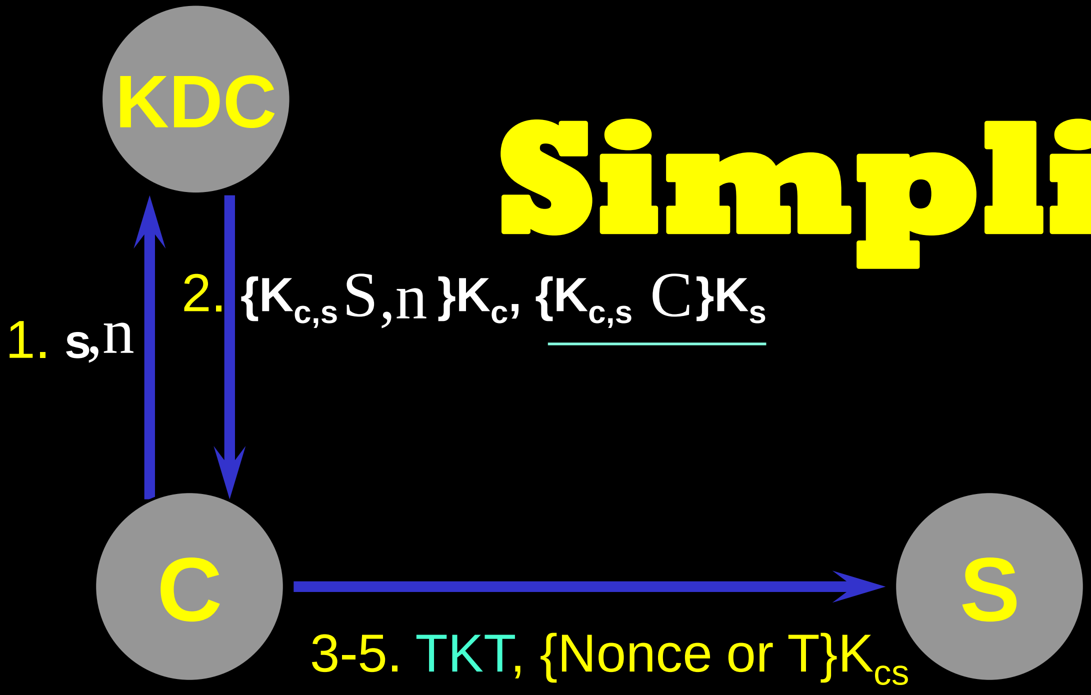
- User sends request to KDC: {s}
- KDC generates a random key: $K_{c,s}$
  - Encrypted twice: $\{K_{c,s\ldots}\}K_c$, $\{K_{c,s\ldots}\}K_s$
  - $\{K_{c,s\ldots}\}K_s$ called ticket
  - Ticket plus $K_{c,s}$ called credentials
  - Ticket is opaque and forwarded with application request
- No keys ever traverse net in the clear

Kerberos or Needham Schroeder

Third-party authentication service

- Distributes session keys for authentication, confidentiality, and integrity

Simplified

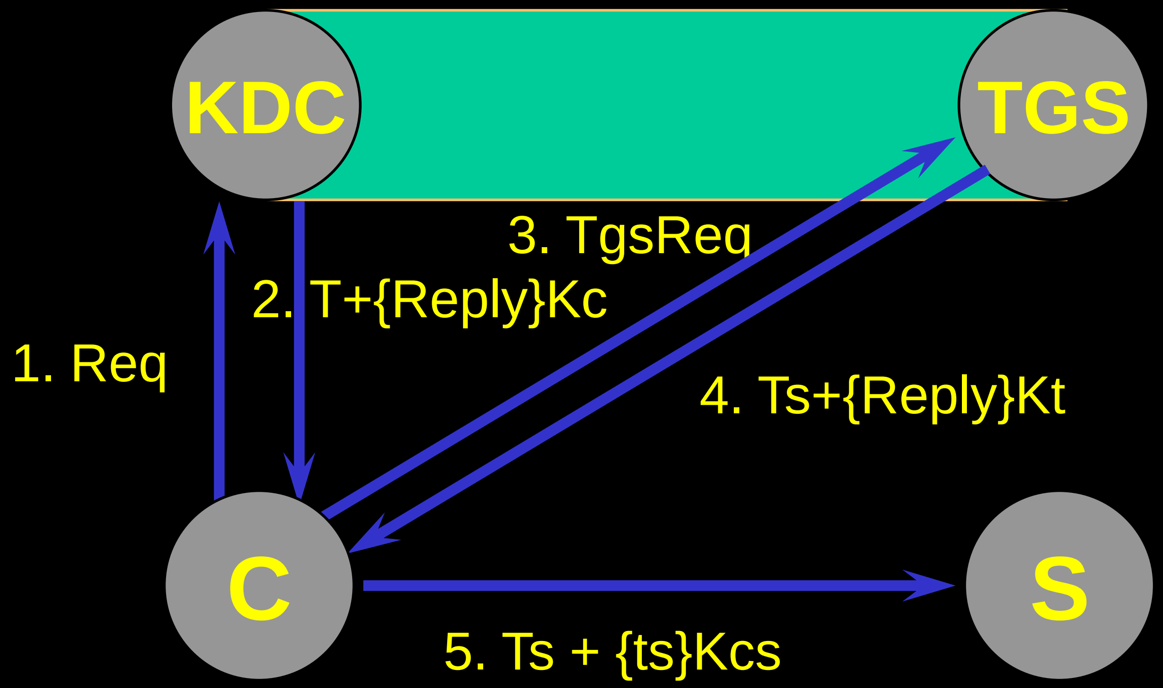

KDC
1. s,n
2. $\{K_{c,s}\, S, n\}K_c$, $\{K_{c,s}\, C\}K_s$
C
S
3-5. TKT, $\{\text{Nonce or T}\}K_{cs}$

Reduce User Key Exposure

- Introduce Ticket Granting Server (TGS)
  - Daily ticket plus session keys
- TGS+AS = KDC
  - This is modified Needham-Schroeder
  - Basis for Kerberos
- Pre-authentication
- Note: not a full solution
  - Makes it slightly harder for adversary.

Kerberos

- Third-party authentication service
  - – Distributes session keys for authentication, confidentiality, and integrity



Key Distribution linked to Authentication

- Its all about knowing who has the keys.
- Authentication is really a topic for next lecture, but the tight linkage with key management is the reason that we covered the Kerberos authentication system in the past few slides.

CSci530: Security Systems

Lecture 4 – September 10, 2021
Key Management (continued) then Authentication and Identity Management

Dr. Clifford Neuman
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http://ccss.usc.edu/530

Public Key Distribution

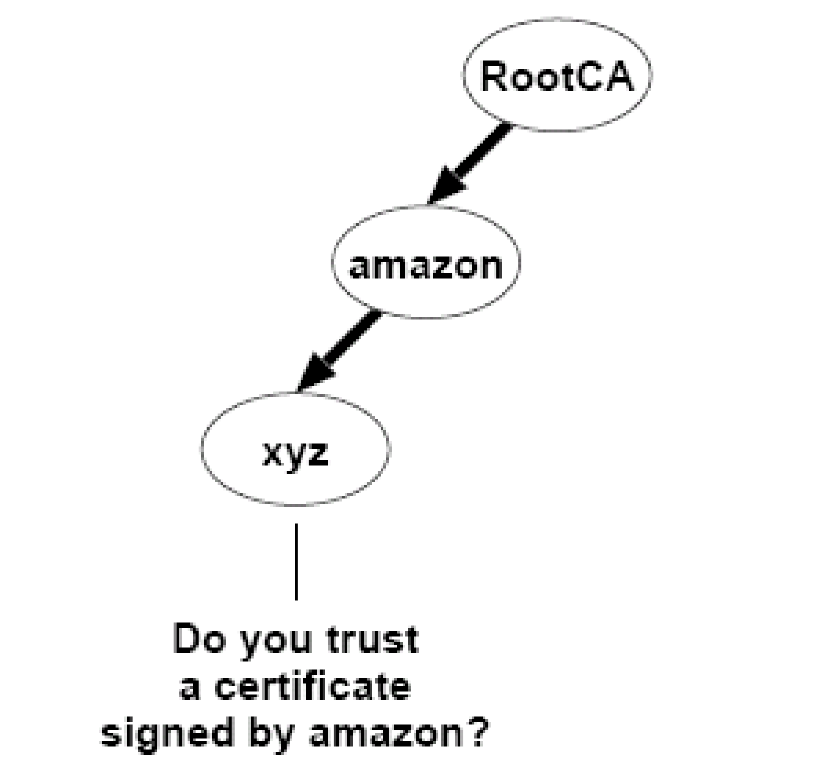
- Public key can be public!
  - How does either side know who and what the key is for? Private agreement? (Not scalable.)
- Does this solve key distribution problem?
  - No – while confidentiality is not required, integrity is.
- Still need trusted third party

Key Management

- Key management is where much security weakness lies
  - Choosing keys
  - Storing keys
  - Communicating keys

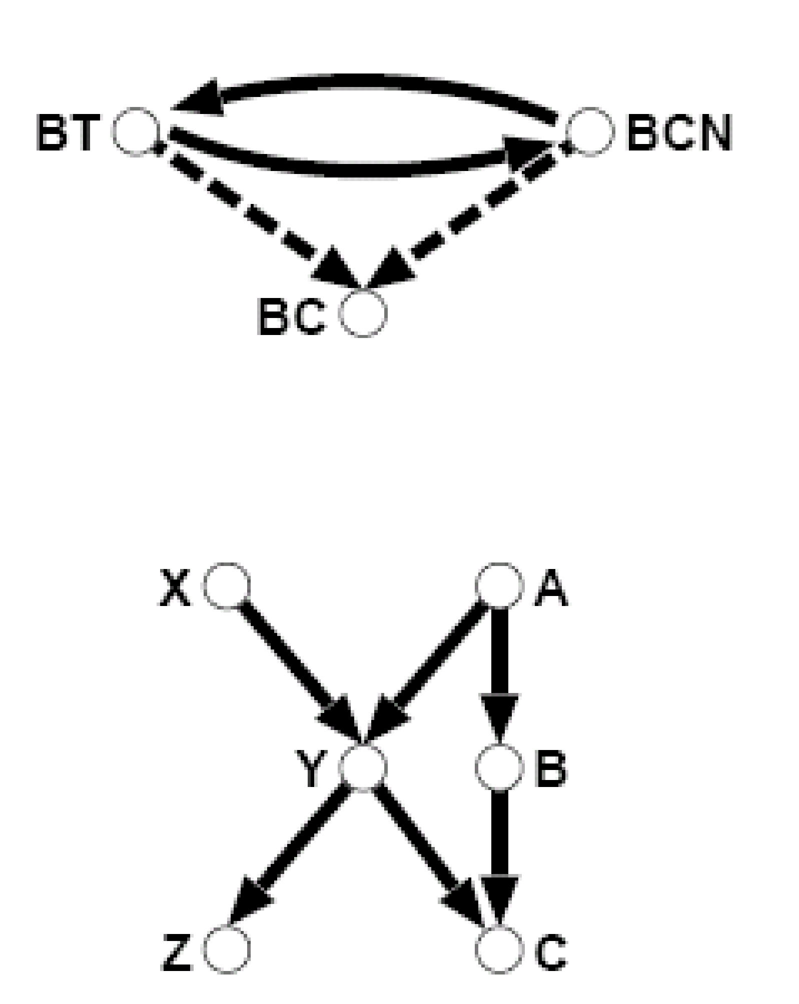
Certification Infrastructures

- Public keys represented by certificates
- Certificates signed by other certificates
  - User delegates trust to trusted certificates
  - Certificate chains transfer trust up several links



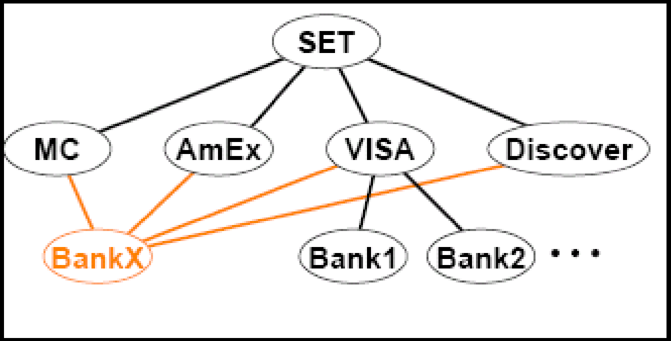
Examples

- PGP
  - "Web of Trust"
  - Can model as connected digraph of signers
- X.500
  - Hierarchical model: tree (or DAG?)
  - (But X.509 certificates use ASN.1!)



Examples

- SSH
  - User keys out of band exchange.
  - Weak assurance of server keys.
    - Was the same host you spoke with last time.
  - Discussion of benefits
- SET
  - Hierarchical
  - Multiple roots
  - Key splitting



Key Distribution

- Conventional cryptography
  - Single key shared by both parties
- Public Key cryptography
  - Public key published to the world
  - Private key known only by owner
- Third party certifies or distributes keys
  - Certification infrastructure
  - Authentication

Recovery from exposed keys

- Revocation lists (CRL’s)
  - Long lists
  - Hard to propogate
- Lifetime / Expiration
  - Short life allows assurance of validitiy at time of issue.
- Realtime validation
  - Online Certificate Status Protocol (OCSP)
- What about existing messages?

Practical use of keys

- Email (PEM or S/MIME or PGP)
  - Hashes and message keys to be distributed and signed.
- Conferencing
  - Group key management (discussed later)
- Authentication (next lecture)
- SSL
  - And other "real time" protocols
  - Key establishment

Key Management Overview

- Key size vs. data size
  - Affects security and usability
- Reuse of keys
  - Multiple users, multiple messages
- Initial exchange
  - The bootstrap/registration problem
  - Confidentiality vs. authentication

Key Management Review

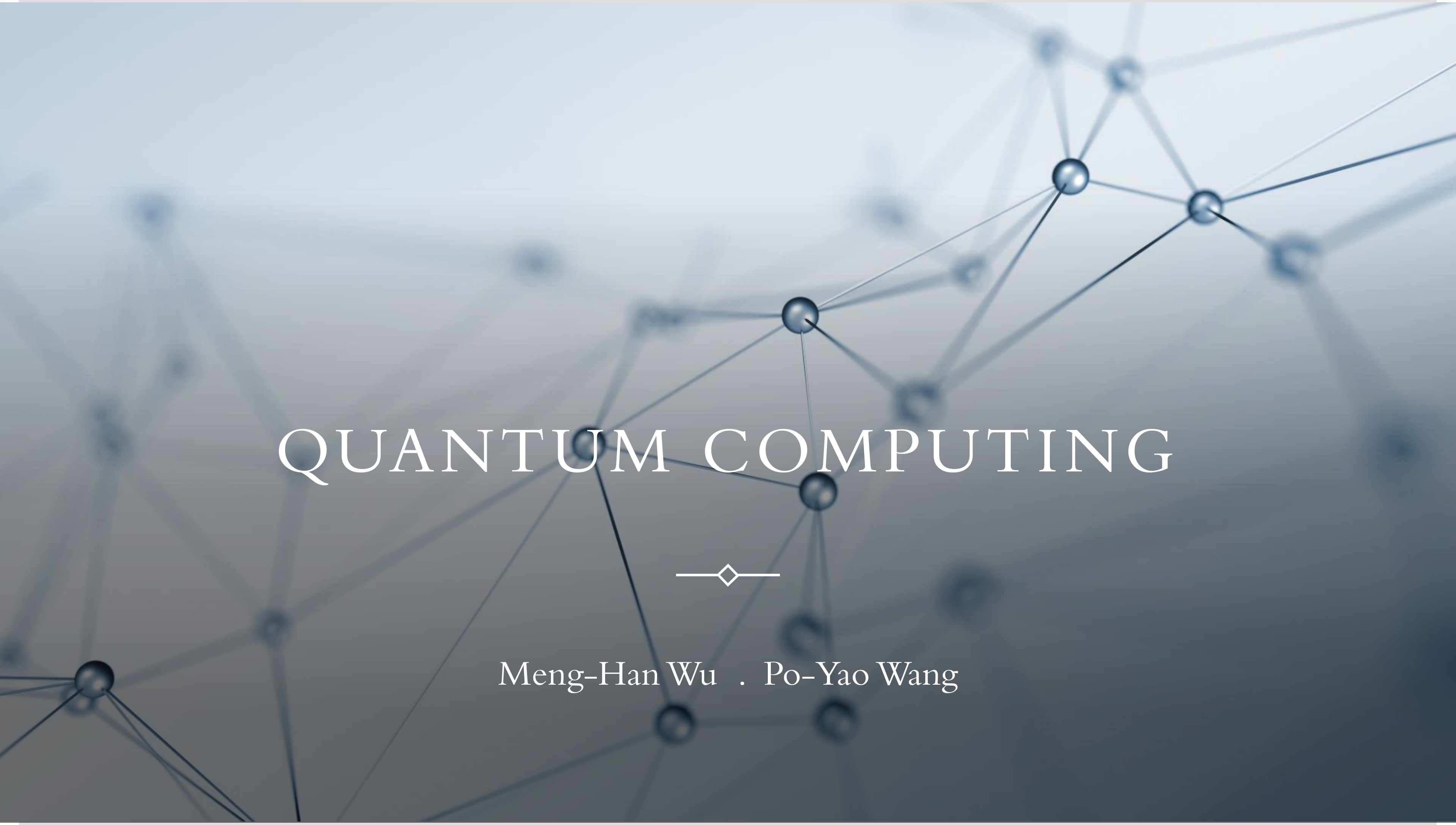
- KDC's
  - Generate and distribute keys
  - Bind names to shared keys

Key Management Overview

- Who needs strong secrets anyway
  - Users?
  - Servers?
  - The Security System?
  - Software?
  - End Systems?
- Secret vs. Public

Group Key Management

- Group key vs. Individual key
  - Identifies member of groups vs. which member of group
  - PK slower but allows multiple verification of individuals



QUANTUM COMPUTING

Meng-Han Wu . Po-Yao Wang

WHAT IS QUANTUM COMPUTING?

- Based on physics, with certain algorithm (like: Shor‘s Algorithm), it can expedite the **Integer Factorization** => **XXXX * XXXX = 2293201 ?**
- “Cryptographically Relevant Quantum Computer (CRQC)” by National Security Agency (NSA - 2021.08)
- Affected: public-key cryptography (e.g. **RSA**, **Diffie–Hellman**)
- Much less affected: symmetric cryptography (e.g. **AES**)

PROGRESS OF QUANTUM COMPUTING

- IBM/Google have announced the roadma

  to 1000-up Qubits by this decade.

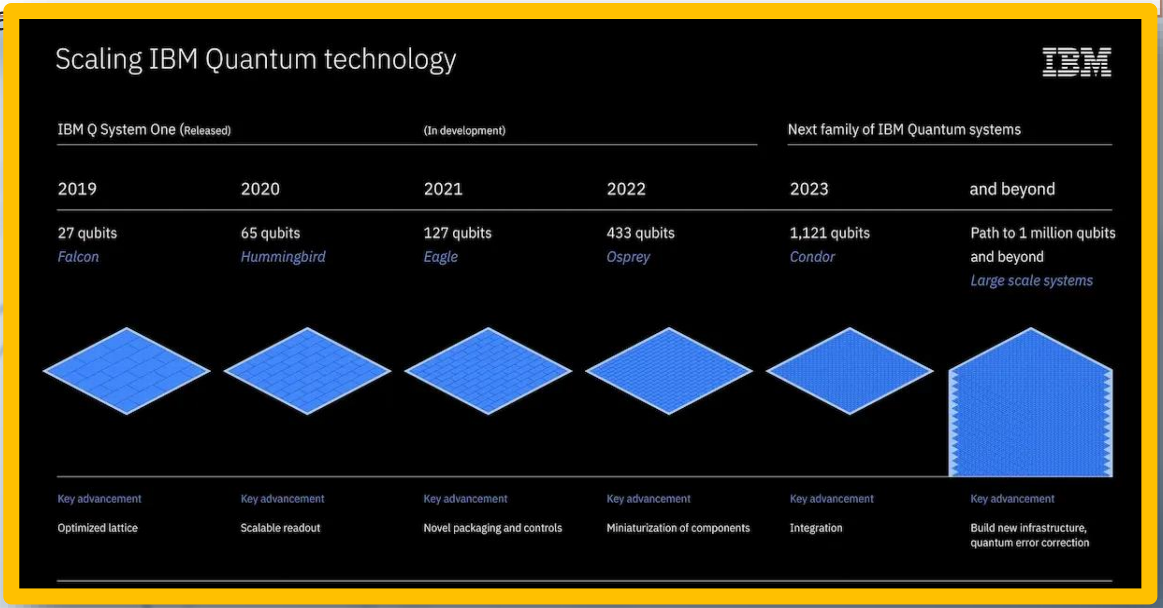
- **Yet** NOT seen any practical application

  “Cryptographically Relevant Quantum

  Computer”

- Is it sufficient to execute **large prime**

  integer factorization?

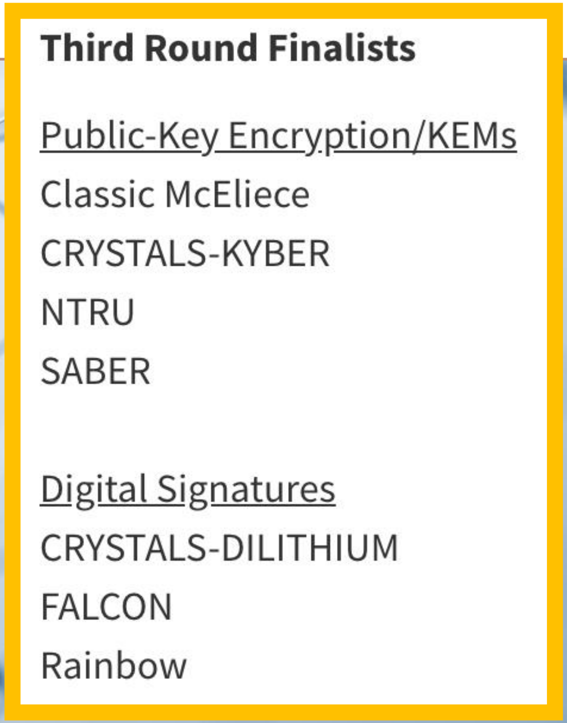


Scaling IBM Quantum technology

IBM Q System One (Released)		(In development)		Next family of IBM Quantum systems	
2019	2020	2021	2022	2023	and beyond
27 qubits *Falcon*	65 qubits *Hummingbird*	127 qubits *Eagle*	433 qubits *Osprey*	1,121 qubits *Condor*	Path to 1 million qubits and beyond *Large scale systems*
Key advancement Optimized lattice	Key advancement Scalable readout	Key advancement Novel packaging and controls	Key advancement Miniaturization of components	Key advancement Integration	Key advancement Build new infrastructure, quantum error correction

PROGRESS OF POST-QUANTUM CRYPTOGRAPHY

- **NIST** started the Post-Quantum Cryptography (PQC) standardization process in 2016.
- Currently running **the Third Round** of process
- **7 Finalists** and 8 Alternates in fields: Public-Key Encryption/KEMs and Digital Signatures
- By 2024 the draft standards will be available



Third Round Finalists

Public-Key Encryption/KEMs

Classic McEliece

CRYSTALS-KYBER

NTRU

SABER

Digital Signatures

CRYSTALS-DILITHIUM

FALCON

Rainbow

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Group Key Management Issues

- Revoking access
  - Change messages, keys, redistribute
- Joining and leaving groups
  - Does one see old message on join
  - How to revoke access
- Performance issues
  - Hierarchy to reduce number of envelopes for very large systems
  - Hot research topic

Group Key Management Approaches

- Centralized
  - – Single entity issues keys
  - – Optimization to reduce traffic for large groups
  - – May utilize application specific knowledges
- Decentralized
  - – Employs sub managers
- Distributed
  - – Members do key generation
  - – May involve group contributions

Look Forward
Security Architectures

- DSSA
  - Delegation is the important issue
    - Workstation can act as user
    - Software can act as workstation
      - if given key
    - Software can act as developer
      - if checksum validated
  - Complete chain needed to assume authority
  - Roles provide limits on authority – new sub-principal

CSci530: Security Systems

Lectures 4&5 – September 17&24, 2021
Authentication

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Identification vs. Authentication

Identification

- Associating an identity with an individual, process, or request

Authentication

- – Verifying a claimed identity

Basis for Authentication

Ideally

- Who you are

Practically

- Something you know
- Something you have
- Something about you
  - (Sometimes mistakenly called things you are)

Something you know

- Password or Algorithm
  - e.g. encryption key derived from password
- Issues
  - Someone else may learn it
    - Find it, sniff it, trick you into providing it
  - Other party must know how to check
  - You must remember it
  - How stored and checked by verifier

Examples of Password Systems

- Verifier knows password
- Encrypted Password
  - One way encryption
- Third Party Validation

Attacks on Passwords

Brute force

Dictionary

Pre-computed Dictionary

Guessing

Finding elsewhere

General Problems with Password

- Space from which passwords Chosen
  - Too many passwords
    - And what it leads to
  - Too few passwords
    - i.e. password re-use
- That you need to present the password to use it
  - Compromise of verifier affects password.

What makes for a good password

How some systems define good passwords:

- MickeyMinniePlutoHueyLouieDewey DonaldGoofyWashington

Other attacks on passwords

- Social Engineering attacks
  - Including Phishing

CSci530: Security Systems

Lectures 5 – September 24, 2021
Authentication

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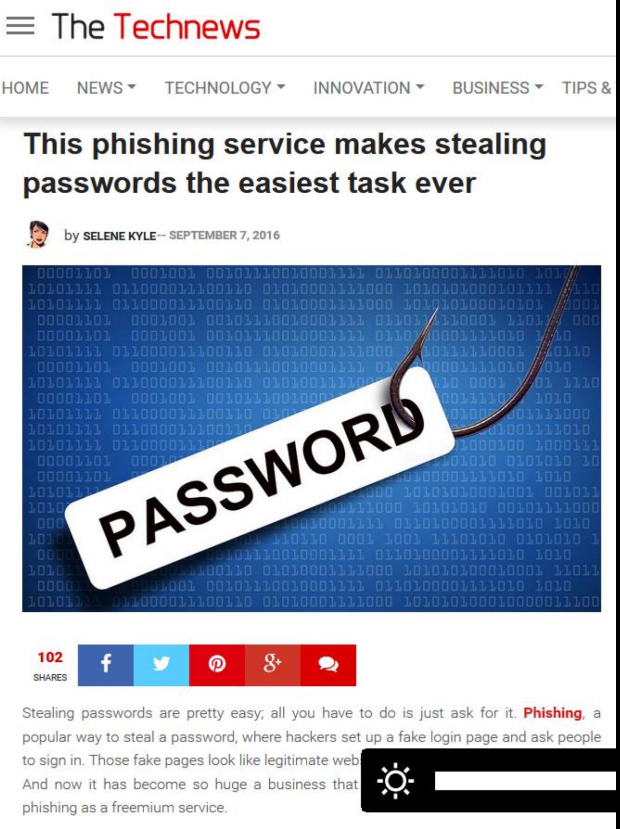
Recent News



This phishing service makes stealing passwords the easiest task ever

by SELENE KYLE -- SEPTEMBER 7, 2016

Stealing passwords are pretty easy; all you have to do is just ask for it. **Phishing**, a popular way to steal a password, where hackers set up a fake login page and ask people to sign in. Those fake pages look like legitimate web

And now it has become so huge a business that

phishing as a freemium service.

Phishing is now (and has been) an automated process.

Discussion:

- Why we need to move away from passwords.

What are the effective alternatives.

Something you Have

- Cards
  - Mag stripe (= password)
  - Smart card, USB key
  - Time varying password
- Issues
  - How to validate
  - How to read (i.e. infrastructure)

Case Study – RSA SecureID

Claimed - Something You Have

- Reduced to something they know

How it works:

- Seed
- Synchronization

Compromises:

- RSA Break-in
- Or man in the middle

Something about you

- Biometrics
  - Measures some physical attribute
    - Iris scan
    - Fingerprint
    - Picture
    - Voice
- Issues
  - How to prevent spoofing
    - Suited when biometric device is trusted, not suited otherwise

Other forms of authentication

IP Address

Caller ID (or call back)

- Now “phone factor” (probably tm)

Past transaction information

- (second example of something you know)

“Enrollment”

How to initially exchange the secret.

- In person enrollment
- Information known in advance
- Third party verification
- Mail or email verification

Multi-factor authentication

- Require at least two of the classes above.
  - e.g. Smart card plus PIN
  - RSA SecurID plus password (AOL)
  - Biometric and password
- Issues
  - Better than one factor
  - Be careful about how the second factor is validated.   E.g. on card, or on remote system.

Single Sign On

“Users should log in once

- And have access to everything”

Many systems store password lists

- Which are easily stolen

Better is encryption based credentials

- Usable with multiple verifiers
- Interoperability is complicating factor.

CSci530: Security Systems

Lectures 5 – September 24, 2021
Authentication and Identity Mgt

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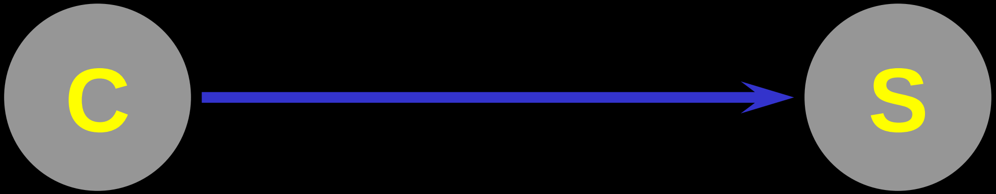
Encryption Based Authentication

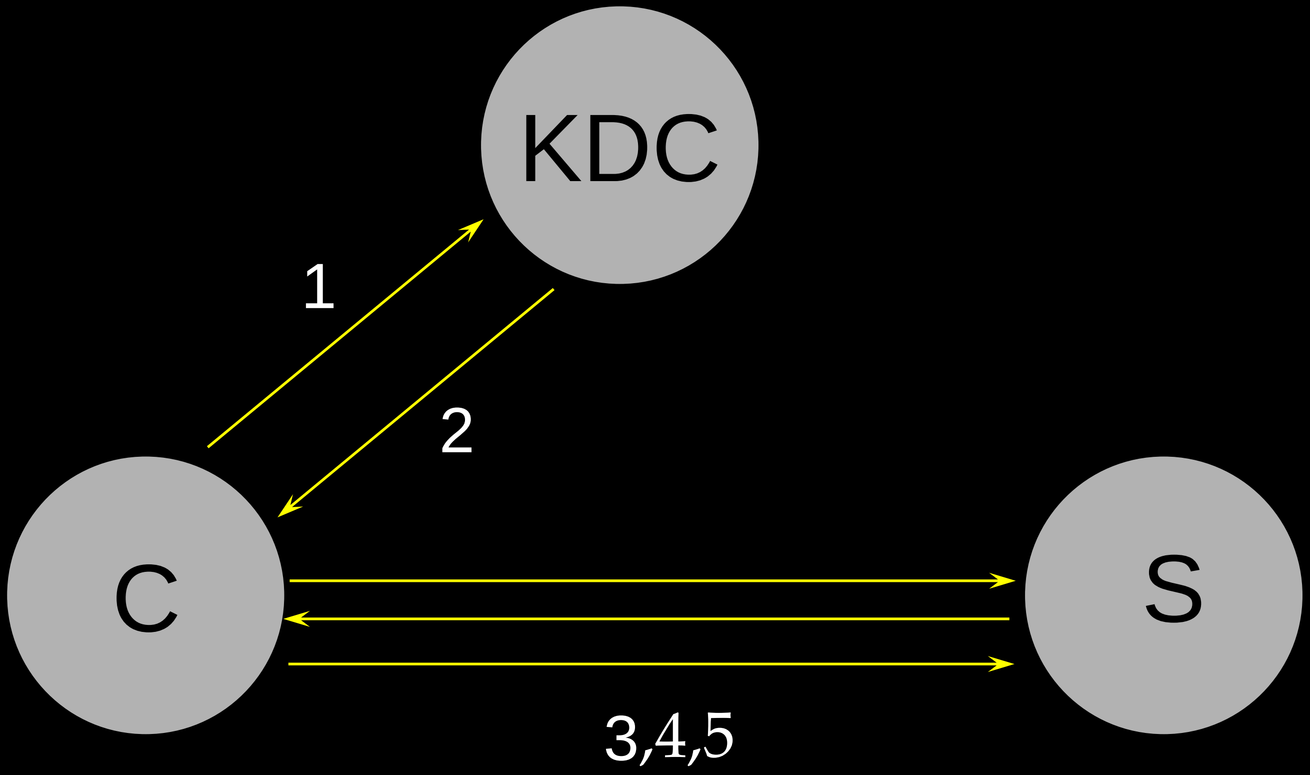
- Proving knowledge of encryption key
  - Nonce = Non repeating value

{Nonce or timestamp}K_{cs}



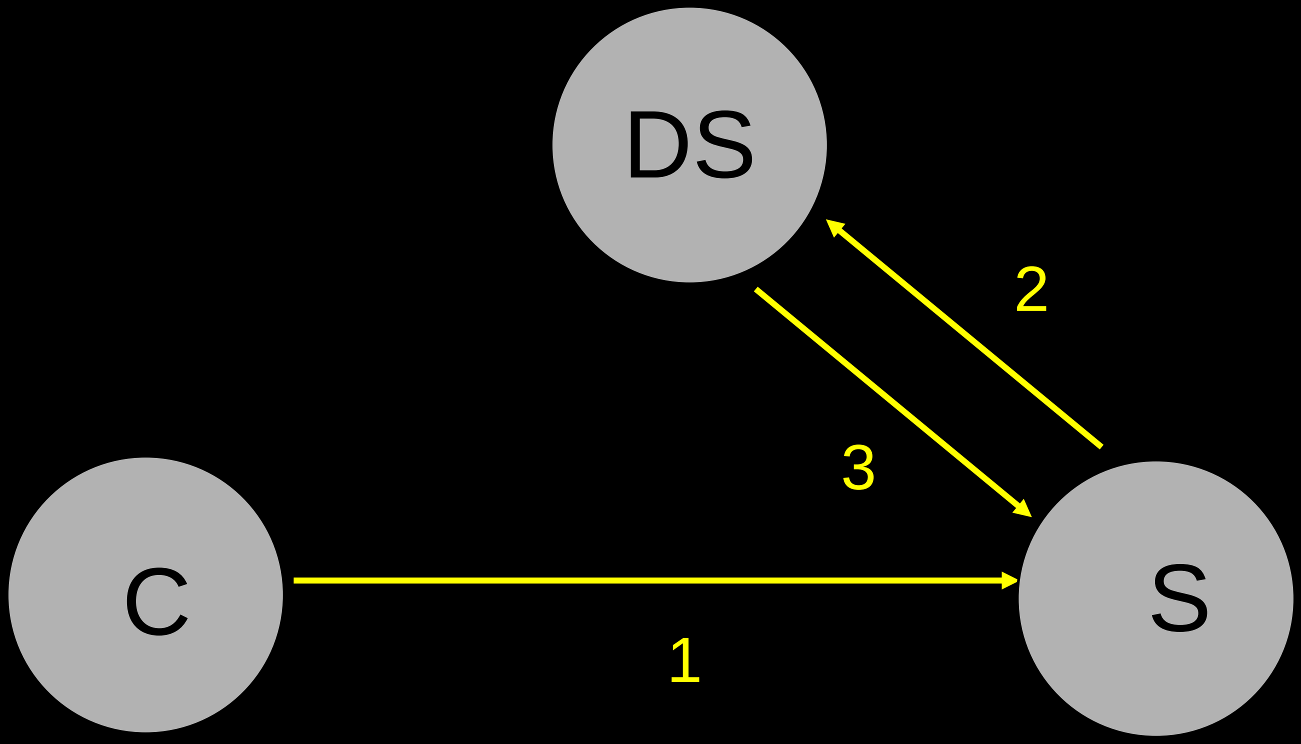
Authentication w/ Conventional Crypto

- Kerberos or Needham Schroeder



Authentication w/ PK Crypto

- Based on public key certificates



Public Key Cryptography (revisited)

- Key Distribution
  - Confidentiality not needed for public key
  - Solves n^2 problem
- Performance
  - Slower than conventional cryptography
  - Implementations use for key distribution, then use conventional crypto for data encryption
- Trusted third party still needed
  - To certify public key
  - To manage revocation
  - In some cases, third party may be off-line

Certificate-Based Authentication

Certification authorities issue signed certificates

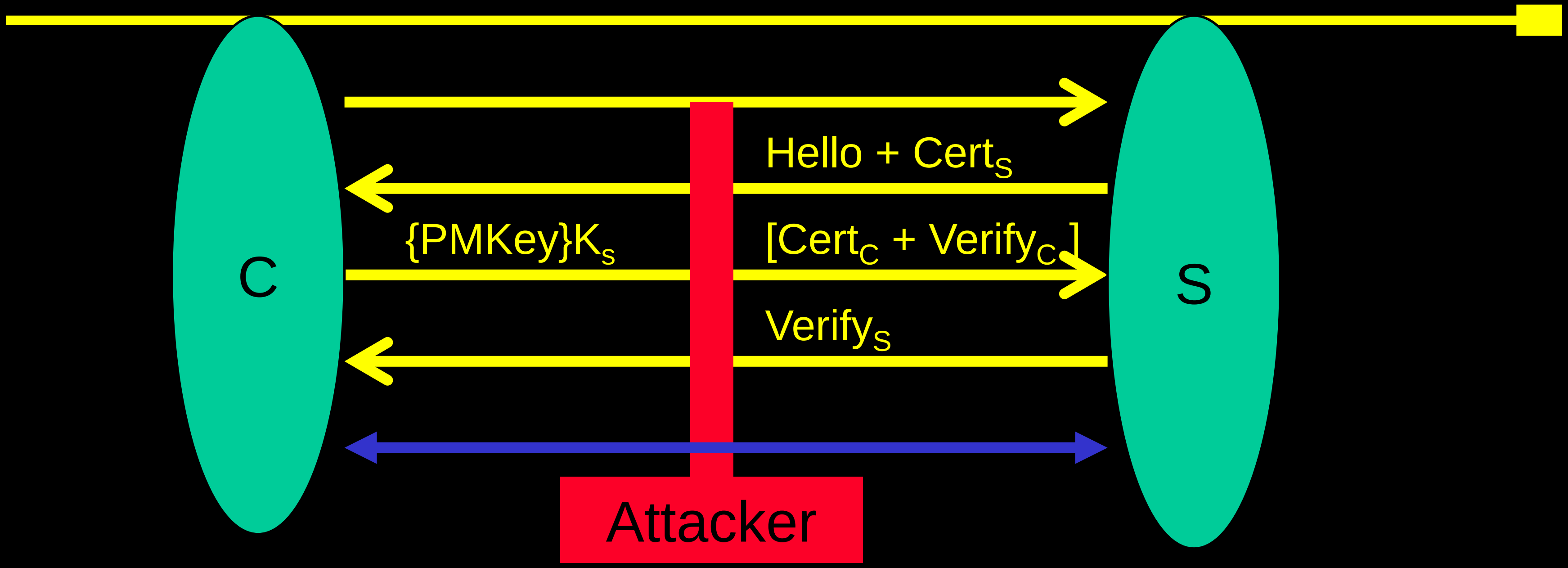
- Banks, companies, & organizations like Verisign act as CA's
- Certificates bind a public key to the name of a user
- Public key of CA certified by higher-level CA's
- Root CA public keys configured in browsers & other software
- Certificates provide key distribution

Certificate-Based Authentication (2)

Authentication steps

- Verifier provides nonce, or a timestamp is used instead.
- Principal selects session key and sends it to verifier with nonce, encrypted with principal's private key and verifier's public key, and possibly with principal's certificate
- Verifier checks signature on nonce, and validates certificate.

Secure Sockets Layer (and TLS)



Encryption support provided between

Browser and web server - below HTTP layer

Client checks server certificate

Works as long as client starts with the correct URL

Key distribution supported through cert steps

Authentication provided by verify steps

Trust models for certification

- X.509 Hierarchical
  - Single root (original plan)
  - Multi-root (better accepted)
  - SET has banks as CA’s and common SET root
- PGP Model
  - “Friends and Family approach” - S. Kent
- Other representations for certifications
- No certificates at all
  - Out of band key distribution
  - SSH

Federated Identity
Passport v Liberty Alliance

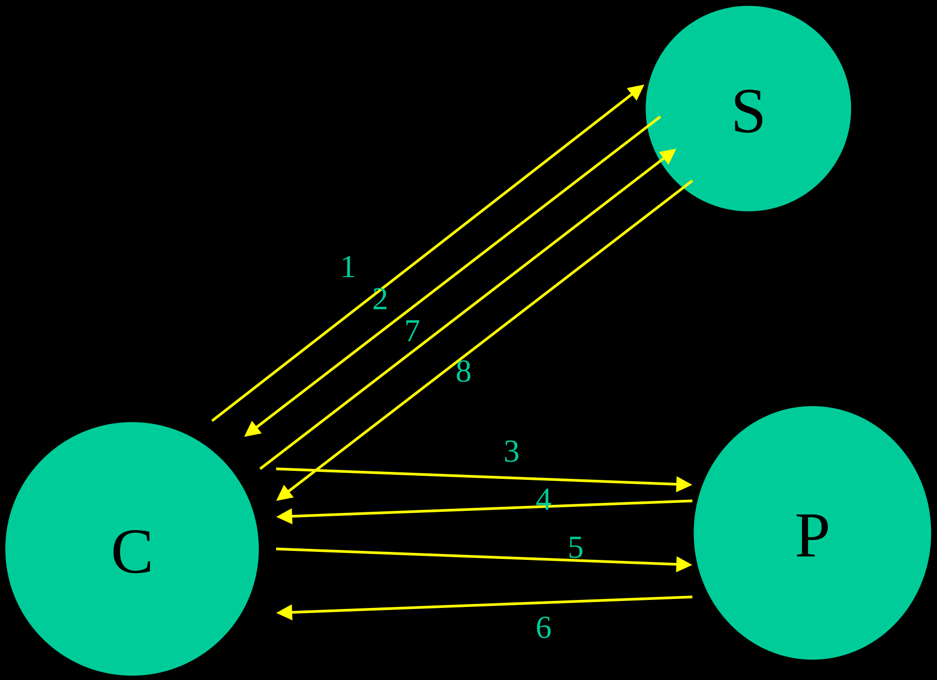
- Two versions of Passport
  - Current deployed version has lots of weaknesses and is centralized
  - Version under development is “federated” and based on Kerberos

Liberty Alliance

  - Loosely federated with framework to describe authentication provided by others.

Passport v1

- Goal is single sign on
- Implemented via redirections



Assigned reading: http://avirubin.com/passport.html

Federated Passport

- Announced September 2001
- Multiple registrars
  - E.g. ISPs register own users
- Kerberos credentials
  - Embedded authorization data to pass other info to merchants.
- Federated Passport is predominantly vaporware today, but .net authentication may be where their federated model went.

Liberty Alliance

- Answer to MS federated Passport
- Design criteria was most of the issues addressed by Federated Passport, i.e. no central authority.
- Got off to slow start, but to date has produced more than passport has.
- Use SAML (Security Association Markup Language) to describe trust across authorities, and what assertions means from particular authorities.
- These are hard problems, and comes to the core of what has kept PKI from being as dominant as orginally envisioned.
- Phased approach: Single sign on, Web service, Federated Services Infrastrcture.

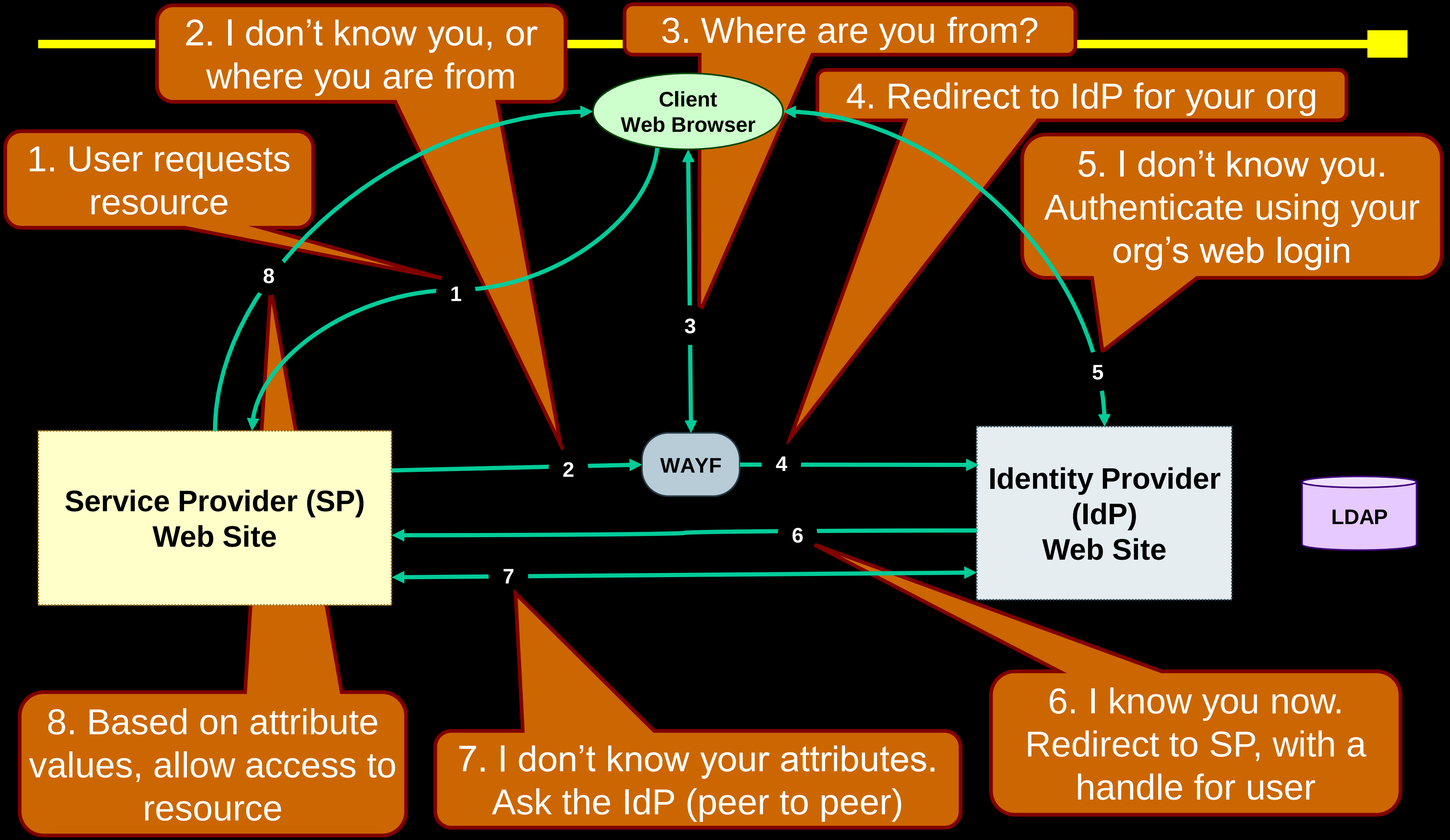
Federated Identity - Shibboleth

- Internet 2 Project
  - Federated Administration
  - Attribute Based Access Control
  - Active Management of Privacy
  - Based on Open SAML
  - Framework for Federation

Shibboleth - Architecture

- Service Provider
  - Browser goes to Resource Manager who users WAYF, and users Attribute Requester, and decides whether to grant access.
- Where are you from service
  - Redirects to correct servers
- Federation

The Shibboleth Protocol



1. User requests resource

2. I don’t know you, or where you are from

3. Where are you from?

4. Redirect to IdP for your org

5. I don’t know you. Authenticate using your org’s web login

6. I know you now. Redirect to SP, with a handle for user

7. I don’t know your attributes. Ask the IdP (peer to peer)

8. Based on attribute values, allow access to resource

Source: Kathryn Huxtable khuxtable@ku.edu 10 June 2005

Generic Security Services API
Moving up the Stack

Standard interface for choosing among authentication methods

- Once an application uses GSS-API, it can be changed to use a different authentication method easily.
- Calls
  - Acquire and release cred
  - Manage security context
    - Init, accept, and process tokens
  - Wrap and unwrap

Authentication in Applications

Unix login

Telnet

RSH

SSH

HTTP (Web browsing)

FTP

Windows login

SMTP (Email)

NFS

Network Access

Unix Login

One way encryption of password

- Salted as defense against pre-computed dictionary attacks
- To validate, encrypt and compare with stored encrypted password
- May use shadow password file

Telnet

A remote login application

- Normally just an unencrypted channel over which plaintext password sent.
- Supports encryption option and authentication options using protocols like Kerberos.

RSH (Remote Shell/Remote Login)

- Usually IP address and asserted account name.
  - Privileged port means accept asserted identity.
  - If not trusted, request unix password in clear.
- Kerberos based options available
  - Kerberos based authentication and optional encryption

Secure Shell (SSH)

- Encrypted channel with Unix login
  - Establish encrypted channel, using public key presented by server
  - Send password of user over channel
  - Unix login to validate password.
- Public key stored on target machine
  - User generate Public Private key pair, and uploads the public key to directory on target host.
  - Target host validates that corresponding private key is known.

Web Browsing (HTTP)

Connect in the clear, Unix Password

Connect through SSL, Unix password

Digest authentication (RFC 2617)

- Server sends nonce
- Response is MD5 checksum of
  - Username, password, nonce URI

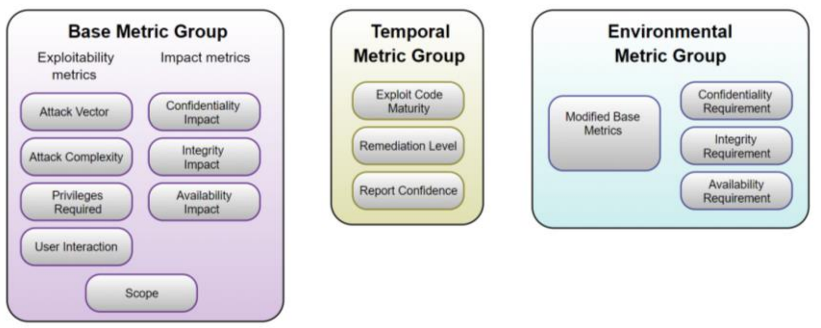
User certificate, strong authentication

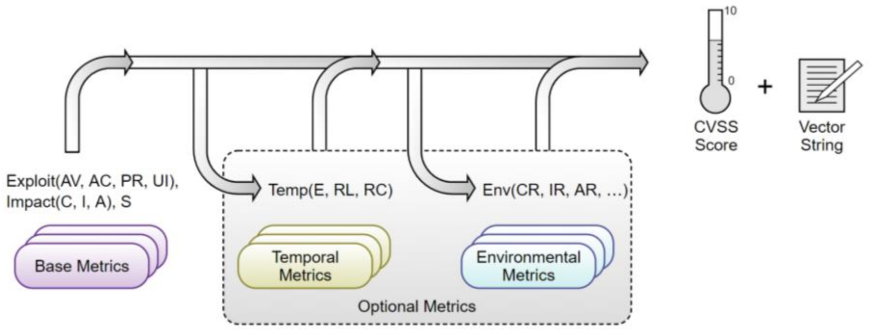
Current Event: Cisco Patches Critical CVE

Michelle Ricci

Common Vulnerability Scoring System (CVSS)

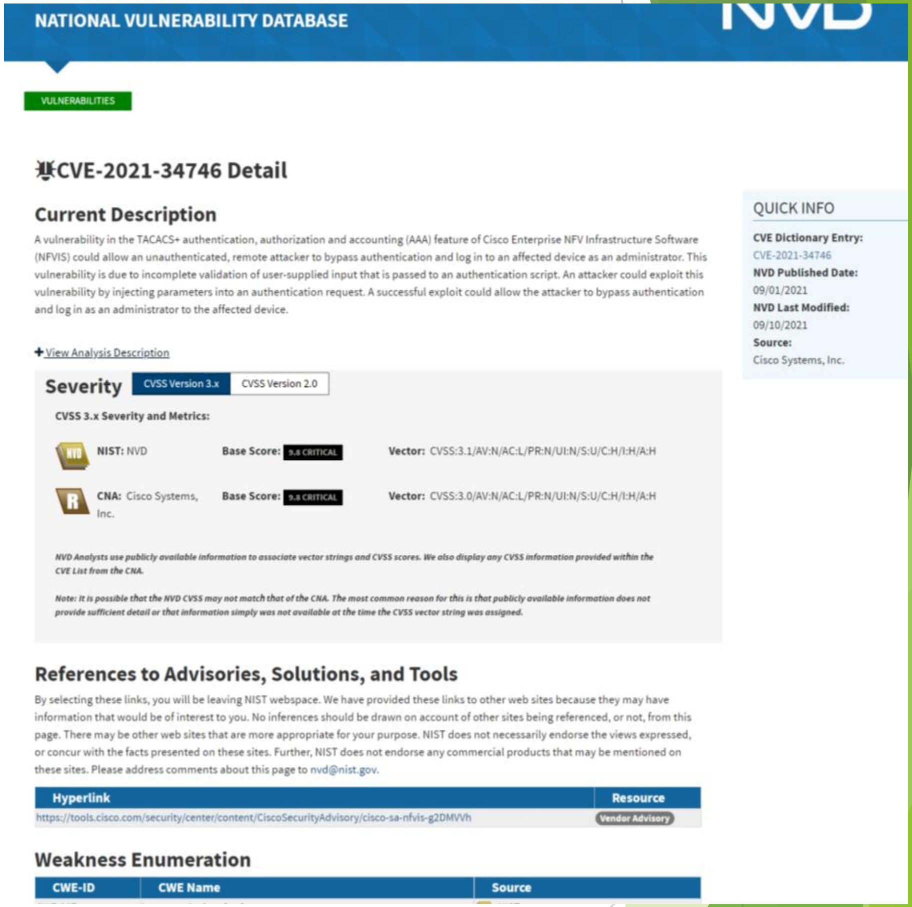
- Evaluates software, hardware, and firmware vulnerabilities
- Scoring 0-10





CVE-2021-34746

- Published in National Vulnerability Database
- Proof of Concept
- No documented use in wild
- 9.8 rating CVSS



NATIONAL VULNERABILITY DATABASE

CVE-2021-34746 Detail

Current Description

A vulnerability in the TACACS+ authentication, authorization and accounting (AAA) feature of Cisco Enterprise NFV Infrastructure Software (NFVIS) could allow an unauthenticated, remote attacker to bypass authentication and log in to an affected device as an administrator. This vulnerability is due to incomplete validation of user-supplied input that is passed to an authentication script. An attacker could exploit this vulnerability by injecting parameters into an authentication request. A successful exploit could allow the attacker to bypass authentication and log in as an administrator to the affected device.

+View Analysis Description

QUICK INFO

CVE Dictionary Entry:
CVE-2021-34746
NVD Published Date:
09/01/2021
NVD Last Modified:
09/10/2021
Source:
Cisco Systems, Inc.

Severity

CVSS 3.x Severity and Metrics:

NIST: NVD **Base Score:** 9.8 CRITICAL **Vector:** CVSS:3.1/AV:N/AC:L/PR:N/UI:N/S:U/C:H/I:H/A:H

CNA: Cisco Systems, Inc. **Base Score:** 9.8 CRITICAL **Vector:** CVSS:3.0/AV:N/AC:L/PR:N/UI:N/S:U/C:H/I:H/A:H

NVD Analysts use publicly available information to associate vector strings and CVSS scores. We also display any CVSS information provided within the CVE List from the CNA.

Note: It is possible that the NVD CVSS may not match that of the CNA. The most common reason for this is that publicly available information does not provide sufficient detail or that information simply was not available at the time the CVSS vector string was assigned.

References to Advisories, Solutions, and Tools

By selecting these links, you will be leaving NIST webspace. We have provided these links to other web sites because they may have information that would be of interest to you. No inferences should be drawn on account of other sites being referenced, or not, from this page. There may be other web sites that are more appropriate for your purpose. NIST does not necessarily endorse the views expressed, or concur with the facts presented on these sites. Further, NIST does not endorse any commercial products that may be mentioned on these sites. Please address comments about this page to nvd@nist.gov.

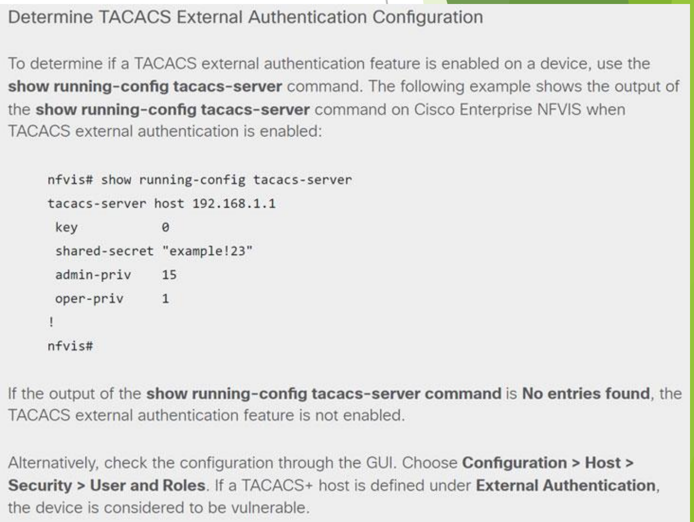
Hyperlink	Resource
https://tools.cisco.com/security/center/content/CiscoSecurityAdvisory/cisco-sa-nfvis-g2DMVVh	Vendor Advisory

Weakness Enumeration

CWE-ID	CWE Name	Source

CVE-2021-34746

- Caused by incomplete user input validation during authentication
- Enables attacker to inject parameters
- Bypass authentication, log in as admin
- Only if TACACS external authenticator is enabled



Determine TACACS External Authentication Configuration

To determine if a TACACS external authentication feature is enabled on a device, use the **show running-config tacacs-server** command. The following example shows the output of the **show running-config tacacs-server** command on Cisco Enterprise NFVIS when TACACS external authentication is enabled:

```
nfvis# show running-config tacacs-server
tacacs-server host 192.168.1.1
 key           0
 shared-secret "example!23"
 admin-priv    15
 oper-priv     1
!
nfvis#
```

If the output of the **show running-config tacacs-server command** is **No entries found**, the TACACS external authentication feature is not enabled.

Alternatively, check the configuration through the GUI. Choose **Configuration > Host > Security > User and Roles**. If a TACACS+ host is defined under **External Authentication**, the device is considered to be vulnerable.

References

- Lakshmanan, Ravie. “Cisco Issues Patch for Critical Enterprise NFVIS Flaw - PoC Exploit Available.” *The Hacker News*, 4 Sept. 2021, thehackernews.com/2021/09/cisco-issues-patch-for-critical.html.
- “CVSS v3.1 Specification Document.” *FIRST*, 2021, www.first.org/cvss/specification-document.
- “National Vulnerability Database.” *NIST*, 1 Sept. 2021, nvd.nist.gov/vuln/detail/CVE-2021-34746#vulnCurrentDescriptionTitle.

CSci530: Security Systems

Lectures 5 (cont) – October 1, 2021
Authentication and Identity Mgt

Dr. Clifford Neuman

University of Southern California

Information Sciences Institute

File Transfer Protocol

Password based authentication or

GSS-API based authentication

- Including use of Kerberos
- Authentication occurs and then stream is encrypted

Windows Network Login

- In Win2K and later uses Kerberos
- In Win NT
  - Challenge response
  - Server generates 8 byte nonce
  - Prompts for password and hashes it
  - Uses hash to DES encrypt nonce 3 times

Email

- SMTP – To send mail
  - Usually network address based
  - Can use password
  - Can be SSL protected
  - SMTP after POP

Email

- Post Office Protocol
  - Plaintext Password
  - Can be SSL protected
  - Eudora supports Kerberos authent
- IMAP
  - Password authentication
  - Can also support Kerberos

Email – Message Authentication

- PGP and S/MIME
  - Digital Signature on messages
    - Message encrypted in session key
      - Optional
    - Hash of message encrypted in private key
    - Validation using sender’s public key

Email – Message Authentication

SPF and SenderID

- Authenticate domain of sender
- SPF record for domain in DNS
  - Specifies what hosts (i.e. mail server host) can send mail originating from that address.
  - Receivers may validate authorized sender based on record
  - Can falsely reject for forwarded messages

Email – Message Authentication

Domain Keys

- Public key associated with domain in DNS
- Originators MTA attaches signature
  - Authenticates senders domain
  - Not individual sender
  - Signature covers specific header fields and possibly part of message.
- Messages may be forwarded

File System Authentication

Sun’s Network File System

- Typically address based
- Athena Kerberized version
  - Maps authenticated UID’s to addresses
- NFS bult on ONC RPC
  - ONC RPC has stronger Kerberos/GSSAPI support

File System Authentication

- Andrew File System
  - Based on Andrew RPC
  - Uses Kerberos authentication
- OSF’s DCE File System (DFS)
  - Based on DCE RPC
  - Uses Kerberos authenciation

Network Access Servers

Radius

- Problem: Not connected to network until connection established
- Need for indirect authentication
  - Network access server must validate login with radius server.
  - Password sent to radius server encrypted using key between agent and radius server

Delegated Authentication

Usually an authorization problem

How to allow an intermediary to perform operations on your behalf.

- Pass credentials needed to authenticate yourself
- Apply restrictions on what they may be used for.

Proxies

- A proxy allows a second principal to operate with the rights and privileges of the principal that issued the proxy
  - Existing authentication credentials
  - Too much privilege and too easily propagated
- Restricted Proxies
  - By placing conditions on the use of proxies, they form the basis of a flexible authorization mechanism

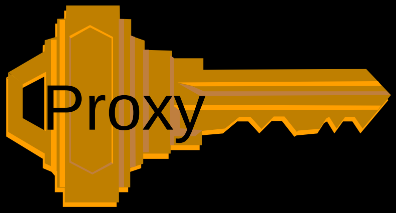
Restricted Proxies

PROXY CERTIFICATE

Conditions:

Use between 9AM and 5PM Grantee is user X, Netmask is 128.9.x.x, must be able to read this fine print, can you

Proxy
0
Gran



- Two Kinds of proxies
  - Proxy key needed to exercise bearer proxy
  - Restrictions limit use of a delegate proxy
- Restrictions limit authorized operations
  - Individual objects
  - Additional conditions

- End of Lecture 5

- Following slides are start of lecture 6

CSci530: Computer Security Systems
Lecture 6 – 1 October 2021
Authorization and Policy

Dr. Clifford Neuman

University of Southern California

Information Sciences Institute

Announcements

Mid-term exam Friday 8th

- 100 minutes
  - Logistics: Start of Lecture Period
- Review during Afternoon Lab Instruction
  - Past exams posted on web site

Authorization

- Final goal of security
  - Determine whether to allow an operation.
- Depends upon
    - Policy
    - Possibly authentication
    - Other characteristics

The role of policy in security architecture

Policy – Defines what is allowed and how the system and security mechanisms should act.

Enforced By

Mechanism – Provides protection interprets/evaluates (firewalls, ID, access control, confidentiality, integrity)

Implemented as:

Software: which must be implemented correctly and according to sound software engineering principles.

Two Kinds of Policy

- Specific criteria evaluated by a system (reference monitor) to decide whether an action is permitted.
  - This will be the definition we use in most of this lecture.
- But also, statements and requirements imposed on the operation of a system, such as required security characteristics, etc.
  - Organization Policy
  - Public Policy

Public Policy: Executive Order on Cybersecurity

Sara Melotte

About Executive Order 14028

Executive order manages operations by the Federal Government, does not require approval from Congress, and acts much like federal law

Motivation: there have been several recent cyberattacks (eg: SolarWinds and Colonial Pipeline Hack), and responses to security breaches lack consistency

- EO 14028 was signed May 12, 2021
- Consists of 11 sections
- Outlines actions to be taken by public (and private) sectors for improving the nation’s cybersecurity breaches prevention and response
- Changes are implemented in phases
- National Institute of Standards and Technology (NIST) plays key role

Most important changes

- More transparency between public and private sectors
  - Eg: remove communication barriers between government and industry with respect to cybersecurity threats and breaches
- Improved software supply chain
  - Eg: more transparency in SW protocols and higher security standards for SW sold to the federal government
  - Eg: label that approved developers can add to their SW and IoT devices to let the public know the product is rated to meet certain security standards (tiers)
- Safety board to assess and learn from security breaches (private + public)
- Move towards cloud technology, multi-factor authorization, and Zero Trust Architecture
  - Agencies must follow NIST’s guidelines (phased approach)
- SOPs for response to security breaches
  - Mandated for government agencies; not for private sector
- Endpoint Detection and Response (EDR) system
  - Support response and containment strategies
- Consistent event logging
  - Allows ability to detect malicious activity, identify trends, and will be shared among various government agencies

Who is impacted?

Most directly:

- Professionals in IT
- Companies selling software to the federal government

Consumers:

- Start seeing labels (such as Energy Star) on software and IoT devices to determine if the product was developed securely

Sources

https://www.whitehouse.gov/briefing-room/presidential-actions/2021/05/12/executive-order-on-improving-the-nations-cybersecurity/

https://www.nist.gov/itl/executive-order-improving-nations-cybersecurity

https://www.americanbar.org/groups/public_education/publications/teaching-legal-docs/what-is-an-executive-order-/

https://www.leidos.com/insights/unpacking-president-bidens-cybersecurity-executive-order

https://www.defendify.io/cybersecurity-blog/the-basics-of-executive-order-14028-and-how-it-may-impact-you

https://iiot-world.com/ics-security/cybersecurity/deciphering-executive-order-14028-improving-the-nations-cybersecurity/

Policy: The Access Matrix

- Policy represented by an Access Matrix
  - Also called Access Control Matrix
  - One row per object
  - One column per subject
  - Tabulates permissions
  - But implemented by:
    - Row – Access Control List
    - Column – Capability List

Instantiations of ACMs

- Capabilities
  - For each principal, list objects and actions permitted for that principal
  - Corresponds to columns of ACM
  - Example: Kerberos restricted proxies
- The Unix file system is an example of…?

Problems

- Permissions may need to be determined dynamically
  - Time
  - System load
  - Relationship with other objects
  - Security status of host

Problems

- Distributed nature of systems may aggravate this
  - ACLs need to be replicated or centralized
  - Capabilities don’t, but they’re harder to revoke
- Approaches
  - GAA

Policy models: Bell-LaPadula

- Discretionary Policy
  - Based on Access Matrix
- Mandatory Policy
  - Top Secret, Secret, Confidential, Unclassified
  - * Property: S can write O if and only if Level S <= Level O
    - Write UP, Read DOWN
  - Categories treated as levels
    - Form a matrix

(more models later in the course)

Other Policy Models

- Mandatory Acces Control
  - Bell-Lepadula is an example
- Discretionary Access Control
  - Many examples
- Role Based Access Control
- Integrity Policies
  - Biba Model – Like BellLepadula but inverted
  - Clark Wilson
    - Constrained Data, IVP and TPs

Role Based Access Control

- Similar to groups in ACLs, but more general.
- Multiple phases
  - Administration
  - Session management
  - Access Control
- Roles of a user can change
  - Restrictions may limit holding multiple roles simultaneously or within a session, or over longer periods.
  - Supports separation of roles
- Maps to Organization Structure

Integrity Policies

- Biba Model – Like BellLepadula but inverted
- Clark Wilson
  - Constrained Data, IVP and TPs

Authorization Examples

- Access Matrix
- Access Control Lists
  - .htaccess (web servers)
  - Unix file access (in a limited sense)
    - On login lookup groups
  - SSH Authorized Keys
- Capabilities
  - Unix file descriptors
  - Proxies mix ACLs and capabilities

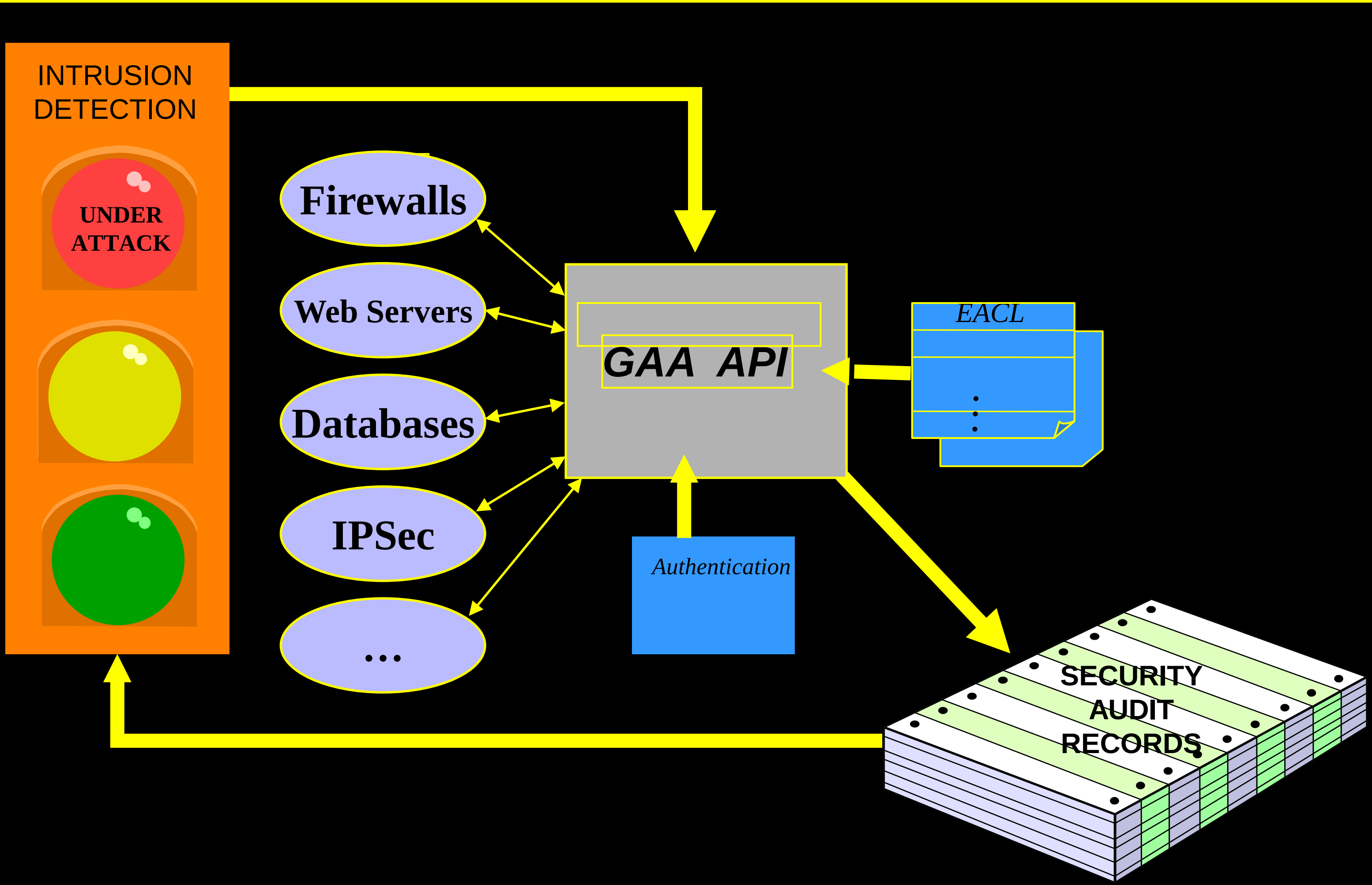
Security is more than mix of point solutions

- **Today's security tools work with no coordinated policy**
  - **Firewalls and Virtual Private Networks**
  - **Authentication and Public Key Infrastructure**
  - **Intrusion Detection and limited response**
- **We need better coordination**
  - **Intrusion response affected at firewalls, VPN's and Applications**
  - **Not just who can access what, but policy says what kind of encryption to use, when to notify ID systems.**
- **Tools should implement coordinated policies**
  - **Policies originate from multiple sources**
  - **Policies should adapt to dynamic threat conditions**
  - **Policies should adapt to dynamic policy changes triggered by activities like September 11th response.**

GAA-API: Integration through Authorization

- **Focus integration efforts on authorization and the management of policies used in the authorization decision.**
  - **Not really new - this is a reference monitor.**
  - **Applications shouldn't care about authentication or identity.**
    - **Separate policy from mechanism**
  - **Authorization may be easier to integrate with applications.**
  - **Hide the calls to individual security services**
    - **E.g. key management, authentication, encryption, audit**

Authorization and Integrated Security Services

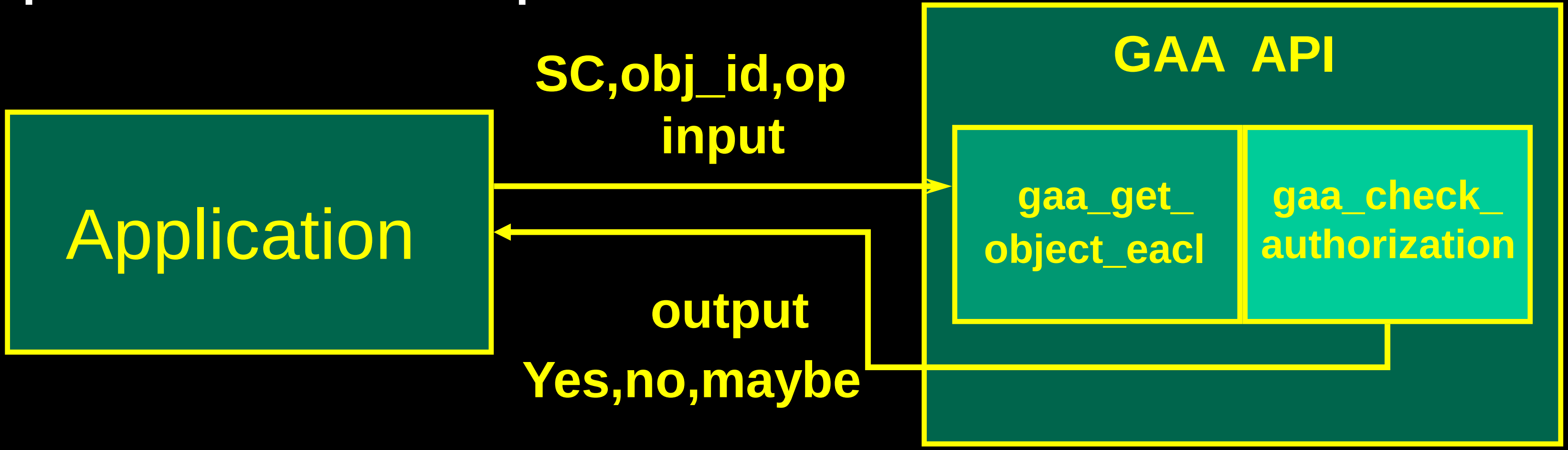


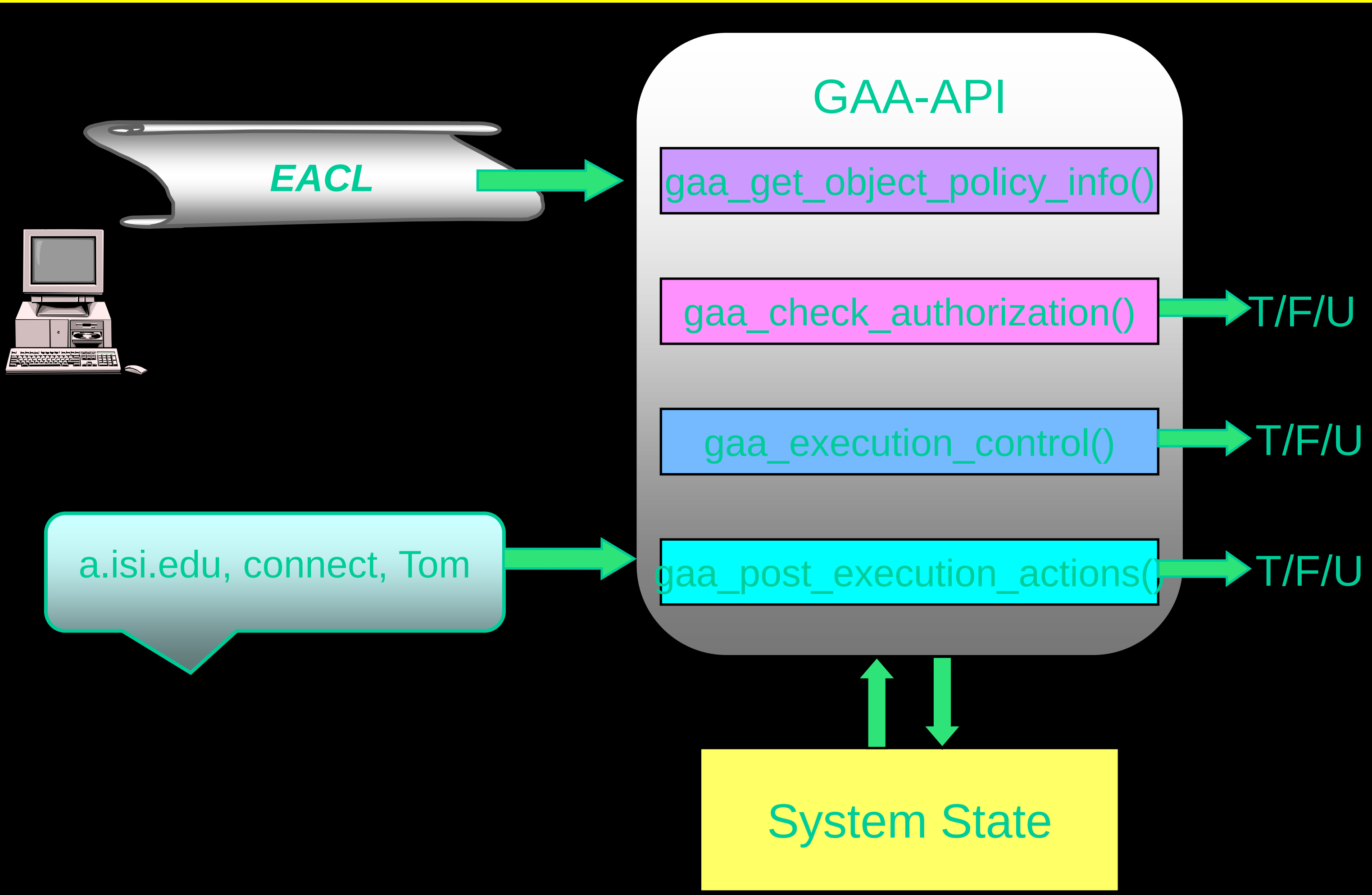
Generic Authorization and Access-control API

Allows applications to use the security infrastructure to implement security policies.

gaa_get_object_policy_info **function called before other GAA API routines which require a handle to object EACL to identify EACLs on which to operate. Can interpret existing policy databases.**

gaa_check_authorization **function tells application whether requested operation is authorized, or if additional application specific checks are required**




EACL
GAA-API
gaa_get_object_policy_info()
gaa_check_authorization()
T/F/U
gaa_execution_control()
T/F/U
a.isi.edu, connect, Tom
gaa_post_execution_actions()
T/F/U
System State

GAA-API Policies originate from multiple sources

- **Discretionary policies associated with objects**
  - **Read from existing applications or EACLs**
- **Local system policies merged with object policies**
  - **Broadening or narrowing allowed access**
- **Policies imported from policy/state issuers**
  - **ID system issues state credentials, These credentials may embed policy as well.**
- **Policies embedded in credentials**
  - **These policies attach to user/process credentials and apply to access by only specific processes.**
- **Policies evaluated remotely**
  - **Credential issuers (e.g. authentication and authorization servers) evaluate policies to decide which credentials to issue.**

Communicating threat conditions

- Threat Conditions and New Policies carried in signed certificates
  - Added info in authentication credentials
  - Threat condition credential signed by ID system
- Base conditions require presentation or availability of credential
  - Matching the condition brings in additional policy elements.

Integrating security services

The API calls must be made by applications.

- This is a major undertaking, but one which must be done no matter how one chooses to do authorization.

These calls are at the control points in the app

- They occur at auditable events, and this is where records should be generated for ID systems
- They occur at the places where one needs to consider dynamic network threat conditions.
- Adaptive policies use such information from ID systems.
- They occur at the right point for billable events.

Advances Needed in Policy

- Ability to merge & apply policies from many sources
  - Legislated policies
  - Organizational policies
  - Agreed upon constraints
- Integration of Policy Evaluation with Applications
  - So that policies can be uniformly enforced
- Support for Adaptive Policies is Critical
  - Allows response to attack or suspicion
- Policies must manage use of security services
  - What to encrypt, when to sign, what to audit.
  - Hide these details from the application developer.

GAA - Applications and other integration

- – Web servers - apache
- – Grid services - globus
- – Network control – IPsec and firewalls
- – Remote login applications – ssh
- – Trust management
  - – Can call BYU code to negotiate credentials
  - – Will eventually guide the negotiation steps

What dynamic policies enable

- **Dynamic policy evaluation enables response to attacks:**
  - **Lockdown system if attack is detected**
  - **Establish quarantines by changing policy to establish isolated virtual networks dynamically.**
  - **Allow increased access between coalition members as new coalitions are formed or membership changes to respond to unexpected events.**

Policies

- HIPAA, other legislation
- Privacy statements
- Discretionary policies
- Mandatory policies (e.g. classification)
- Business policies

Mechanisms

- Access Matrix
  - Access Control List
  - Capability list
- Unix file system
- Andrew file system
- SSH authorized key files
- Restricted proxies, extended certificates
- Group membership
- Payment

Summary

- Policies naturally originate in multiple places.
- Deployment of secure systems requires coordination of policy across countermeasures.
- Effective response requires support for dynamic policy evaluation.
- Such policies can coordinated the collection of data used as input for subsequent attack analysis.

Review for Mid-term

- Cryptography
  - Basic building blocks
  - Conventional
    - DES, AES, others
  - Public key
    - RSA
  - Hash Functions
  - Modes of operation
    - Stream vs. Block

Review for Mid-term

- Key Management
  - Pairwise key management
  - Key storage
  - Key generation
  - Group key management
  - Public key management
  - Certification

Review for Mid-term

- Authentication: Know, Have, About you
  - Unix passwords
  - Kerberos and NS
  - Public Key
  - Single Sign On
  - Applications and how they do it
  - Weaknesses

Review for Mid-term

- Authorization and Policy:
  - Access Matrix
    - ACL
    - Capability
  - Bell Lapadula
  - Dynamic Policy Management
  - Delegation
  - Importance of getting policy right

F17 Mid-Term Q1: Crypto/Key Management

Matching:

1. AES in Cipher Block Chaining Mode
2. One Time Pad
3. RSA
4. AES in Output Feedback Mode
5. Diffie-Hellman Key Exchange
6. Public Key Infrastructure (use of a Certification Authority)
7. Key Management in Kerberos

a) Involves a Trusted Third Party

b) Involves public keys or public key cryptography (asymmetric)

c) Involves conventional keys or conventional cryptography (symmetric)

d) Strong protection of confidentiality

e) Strong protection of Integrity

f) Requires Initialization Vector

F17 Mid-Term Q2: Short Answer

a. What are the main differences between the Bell-LaPadula model for authorization as compared with the Biba Model. (10 points)

b. Provide two examples for each and discuss two advantages or disadvantages each, for each of authentication based on i) something you know; ii) something you have; and iii) something about you. (for each of these I, ii, and iii, your answer should include the two examples, and then two sentences - those sentences describing and advantage or disadvantage of the approach). (20 points)

c. Provide two examples of information flow policies and explain how they are useful to prevent information disclosure and system compromise. (note that you may need to rely on the discussion in lecture, rather than simply searching for the term in the lecture notes) (10 points)

F17 Mid-Term Q3: Equifax

You have been hired as a consultant to advise on the response to the Equifax data breach. Your new employer understands that you have not taken the section of this class on malicious code, so you are only being asked to advise on technology solutions related to cryptography, identity management, and or policy. You will be asked how changes to the way these services are used in the credit reporting industry can help to mitigate the impact of the Equifax breach, or how these technologies might prevent similar breaches from occurring in the future.

A. Authentication Technologies – Problems with our current approach - What is wrong with the existing form of authentication of individuals applying for credit, and why is this a significant problem following the recent Equifax data beach. In answering this question focus on the initial authentication that is performed during "enrollment" (i.e. opening a new account), rather than the authentication performed after an account has been opened. (10 points)

B. Authentication Technologies – Improving the Situation - Thinking along the lines of federated identity (this is a hint of one possible approach), or along other lines if you choose to do so, suggest alternative ways to "enroll" users for new accounts (e.g. when applying for a new card). Discuss the advantage of your approach as compared with existing techniques. Discuss the limitation of your approach: what does it depend upon for security? Are there cases that it cannot be applied for certain users? How might a criminal attempt to get around the protections provided? What else might you do to mitigate some of these failures? (15 points)

C. Preventing these kinds of breaches in the future – Improving data access policy - It is believed that the attack exploited a known vulnerability in a software package that was used on a web server managed by Equifax. This specific attack could have been prevented if the appropriate patches had been applied, but there are many vulnerabilities that do exist for which the attacks are unknown (sometimes called a zero-day attack) and for which patches are not yet available. To address security comprehensively, we must design our system so that a vulnerable software module does not have significant access to all of the information in an enterprise such as Equifax. Part of that design involves applying policies for access to data (confidentiality and Integrity) that will limit the impact of these inevitable vulnerabilities. Discuss some of the kinds of policies that might be applied in the Equifax system that could reduce the impact of the breach that affected the vulnerable web server.
(15 points)