EE515/IS523
Think Like an Adversary
Lecture 2 Intro+Crypto

Yongdae Kim

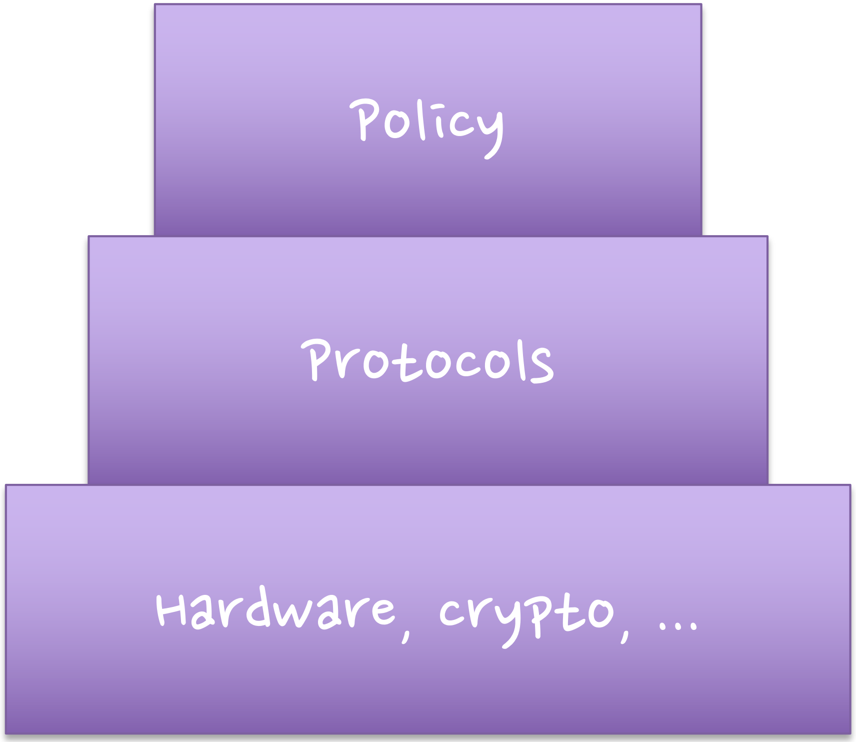
KAIST

Admin

- Homepage
  - http://security101.kr
- Survey
  - Find your group members and discuss about projects

Design Hierarchy

- What are we trying to do?
- How?
- With what?
- Considerations
  - Top-down vs. Bottom-up
  - Iterative
  - Convergence
  - environment change



Goals: Confidentiality

- Confidentiality of information means that it is accessible only by authorized entities

  - Contents, Existence, Availability, Origin, Destination, Ownership, Timing, etc… of:
  - Memory, processing, files, packets, devices, fields, programs, instructions, strings...

Goals: Integrity

- Integrity means that information can only be modified by authorized entities
  - e.g. Contents, Existence, Availability, Origin, Destination, Ownership, Timing, etc… of:
  - Memory, processing, files, packets, devices, fields, programs, instructions, strings...

Goals: Availability

- Availability means that authorized entities can access a system or service.

- A failure of availability is often called Denial of Service:
  - Packet dropping
  - Account freezing
  - Jamming
  - Queue filling

Goals: Accountability

- Every action can be traced to "the responsible party."

- Example attacks:
  - Microsoft cert
  - Guest account
  - Stepping stones

Goals: Dependability

- A system can be relied on to correctly deliver service
- Dependability failures:
  - Therac-25: a radiation therapy machine
    - » whose patients were given massive overdoses (100 times) of radiation
    - » bad software design and development practices: impossible to test it in a clean automated way
  - Ariane 5: expendable launch system
    - » the rocket self-destructing 37 seconds after launch because of a malfunction in the control software
    - » A data conversion from 64-bit floating point value to 16-bit signed integer value

Interacting Goals

- Failures of one kind can lead to failures of another, e.g.:
  - Integrity failure can cause Confidentiality failure
  - Availability failure can cause integrity, confidentiality failure
  - Etc…

Threat Model

- What property do we want to ensure against what adversary?

- Who is the adversary?
- What is his goal?
- What are his resources?
  - e.g. Computational, Physical, Monetary…
- What is his motive?
- What attacks are out of scope?

Terminologies

- Attack (Exploit): attempt to breach system security (DDoS)
- Threat: a scenario that can harm a system (System unavailable)
- Vulnerability: the "hole" that allows an attack to succeed (TCP)
- Security goal: "claimed" objective; failure implies insecurity

Who are the attackers?

- No more script-kiddies

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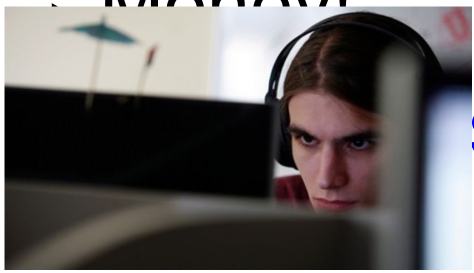
  - Money!



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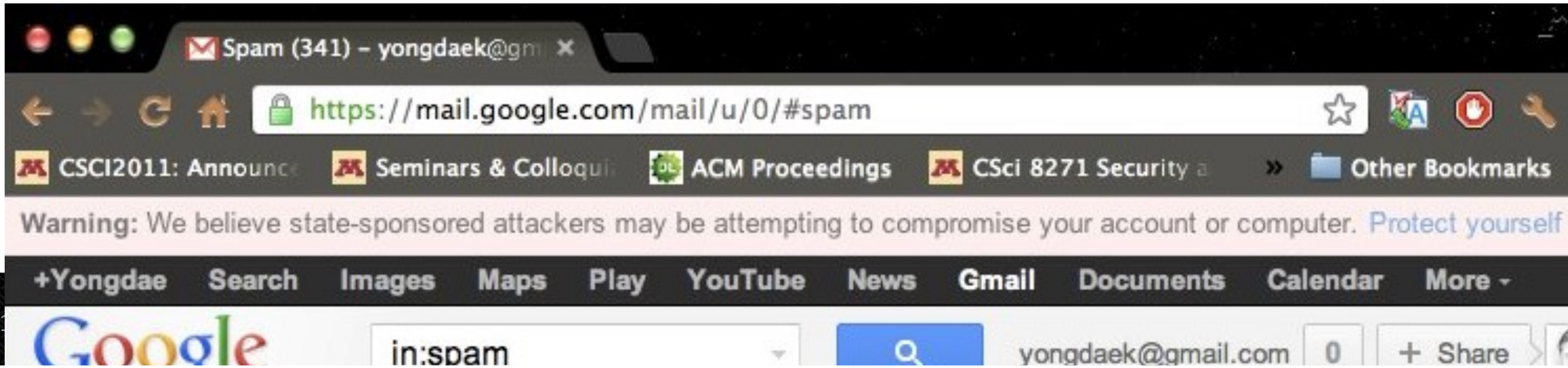
SysSec
System Security Lab

State-Sponsored Attackers

- 2012. 6: Google starts warning users who may be targets of government-sponsored hackers

- 2010 ~: Stuxnet, Duqu, Flame, Gauss, …
  - Mikko (2011. 6): A Pandora's Box We Will Regret Opening

- 2010 ~: Cyber Espionage from China
  - Exxon, Shell, BP, Marathon Oil, ConocoPhillips, Baker Hughes
  - Canada/France Commerce Department, EU parliament
  - RSA Security Inc. SecurID
  - Lockheed Martin, Northrop Grumman, Mitsubushi



Hacktivists

- promoting expressive politics, free speech, human rights, and information ethics
- Anonymous
  - To protest against SOPA, DDoS against MPAA, RIAA, FBI, DoJ, Universal music
  - Attack Church of Scientology
  - Support Occupy Wall Street

- LulzSec
  - Hacking Sony Pictures (PSP jailbreaking)
  - Hacking Pornography web sites
  - DDoSing CIA web site (3 hour shutdown)

Security Researchers

- They tried to save the world by introducing new attacks on systems

- Examples
  - Diebold AccuVote-TS Voting Machine
  - APCO Project 25 Two-Way Radio System
  - Kad Network
  - GSM network
  - Pacemakers and Implantable Cardiac Defibrillators
  - Automobiles, …

Rules of Thumb

- Be conservative: evaluate security under the best conditions for the adversary
- A system is as secure as the weakest link.
- It is best to plan for unknown attacks.

Security & Risk

- The risk due to a set of attacks is the expected (or average) cost per unit of time.
- One measure of risk is Annualized Loss Expectancy, or ALE:

ALE of attack A

$$\sum_{\text{attack } A} (p_A \times L_A)$$

Annualized attack incidence

Cost per attack

Risk Reduction

- A defense mechanism may reduce the risk of a set of attacks by reducing L_A or p_A. This is the gross risk reduction (GRR):

$$\sum_{\text{attack } A} (p_A \times L_A - p'_A \times L'_A)$$

- The mechanism also has a cost. The net risk reduction (NRR) is GRR – cost.

Bug Bounty Program

- Evans (Google): “Seeing a fairly sustained drop-off for the Chromium”
- McGeehan (Facebook): The bounty program has actually outperformed the consultants they hire.
- Google: Patching serious or critical bugs within 60 days
- Google, Facebook, Microsoft, Mozilla, Samsung, …

Nations as a Bug Buyer

- ReVuln, Vupen, Netragard: Earning money by selling bugs
- “All over the world, from South Africa to South Korea, business is booming in what hackers call zero days”
- “No more free bugs.”
- ‘In order to best protect my country, I need to find vulnerabilities in other countries’
- Examples
  - Critical MS Windows bug: $150,000
  - a zero-day in iOS system sold for $500,000
  - Vupen charges $100,000/year for catalog and bug is sold separately
  - Brokers get 15%.

Sony vs. Hackers

2000.8 — Sony Exec — do whatever to protect re

2005.10 — Russinovich — Sony

2007.1 — FTC — Reimburse

2011.1 — Hotz — PS3 Hack

2011.4 — Sony, Hotz — settled

2011.4 — PSN — Hacked

2011. — Son — ½ day recov

2011. 3 $36.27 per share

2011. 6 $24.97 per share

2011.5 — ny Exec — ologized

2011.5 — SOE — Hacked

2011.5 — Sony — outage cost $171M

2011.6 — Sony — Fired security staff

2012.3 — Anon — Posted Unreleased Michael Jackson video

Patco Construction vs. Ocean Bank

- Hacker stole ~$600K from Patco through Zeus
- The transfer alarmed the bank, but ignored

- “commercially unreasonable”
  - Out-of-Band Authentication
  - User-Selected Picture
  - Tokens
  - Monitoring of Risk-Scoring Reports

Auction vs. Customers

- Auction's fault
  - Unencrypted Personal Information
  - It did not know about the hacking for two days
  - Passwords
    - 'auction62', 'auctionuser', 'auction'
  - Malwares and Trojan horse are found in the server.

- Not gulity, because
  - Hacker utilized new technology, and were well-organized.
  - Auctions have too many server.
  - AVs have false alarms.
  - For large company like auction, difficult to use.
  - Causes massive traffic.

Cost of Data Breach

Ponemon Cost of Data Breach Study: 12th year in measuring cost of data breach

Company	Year	Data	Cost (USD)
Anthem	2015	80 M patient and employee records	100M
Ashley Madison	2015	33 M user accounts	850M
Ebay	2014	145M customer accounts	200M
JPMorgan Chase	2014	Financial/Personal Info of 76 M Personal, 7M Small B	1000M
Home Depot	2014	56 M credit card and 53 M email addresses.	80 M
Sony Pictures	2014	Personal Information of 3,000 employees	35 M
Target	2013	40 M credit and debit card, 70 M customer	252 M
Global Payments	2012	1.5M card accounts	90 M
Tricare	2011	5 M Tricare Military Beneficiary	130 M
Citi Bank	2011	360,000 Credit Card	19 M
Hearland	2009	130M Card	2800 M

Security theater is the practice of

- investing in countermeasures intended to provide the feeling of improved security
- while doing little or nothing to actually achieve it

- Bruce Schneier

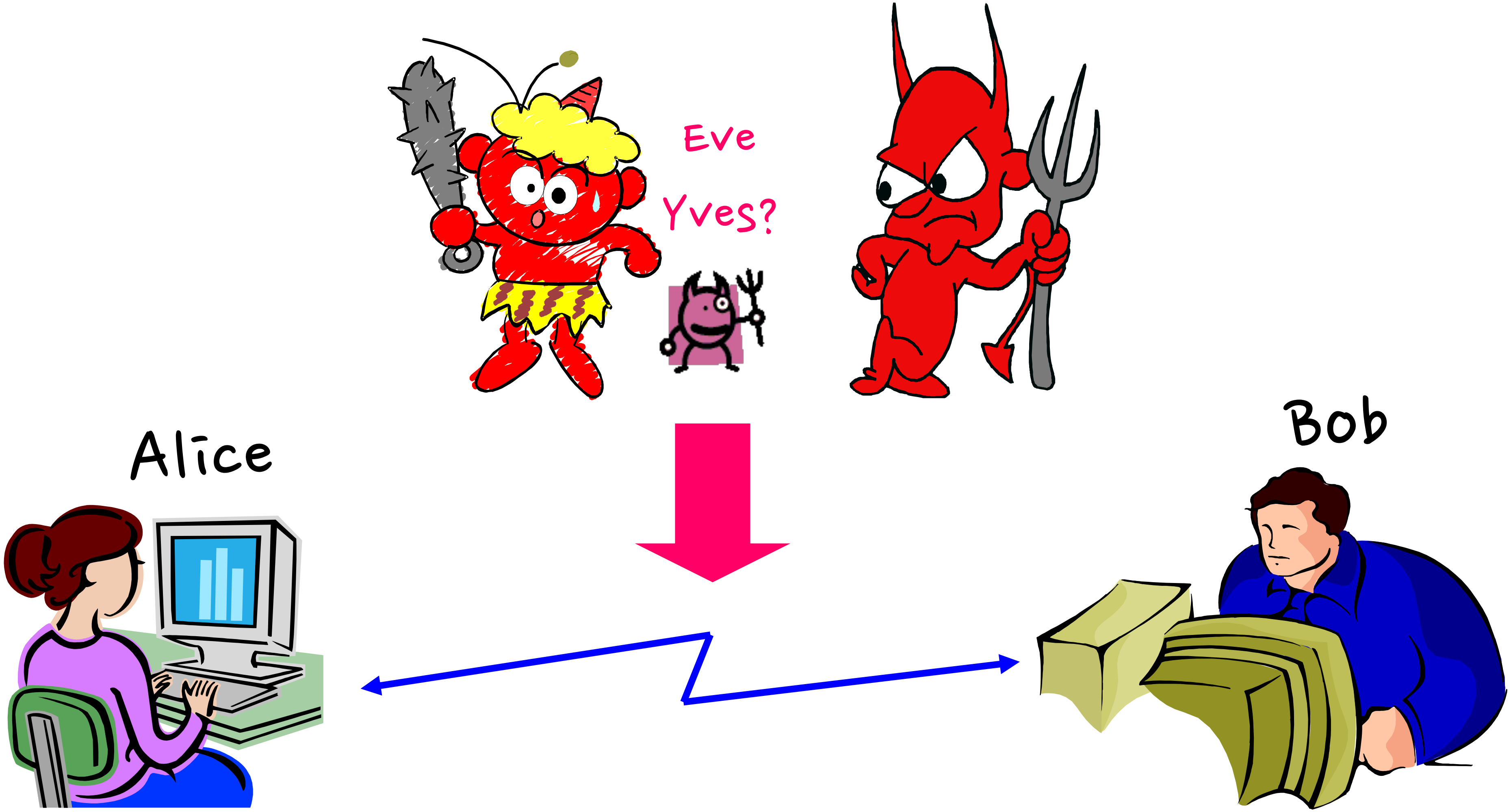
Security of New Technologies

- Most of the new technologies come with new and old vulnerabilities.
  - Old vulnerabilities: OS, Network, Software Security, …
  - Studying old vulnerabilities is important, yet less interesting.
  - e.g. Stealing Bitcoin wallet, Drone telematics channel snooping

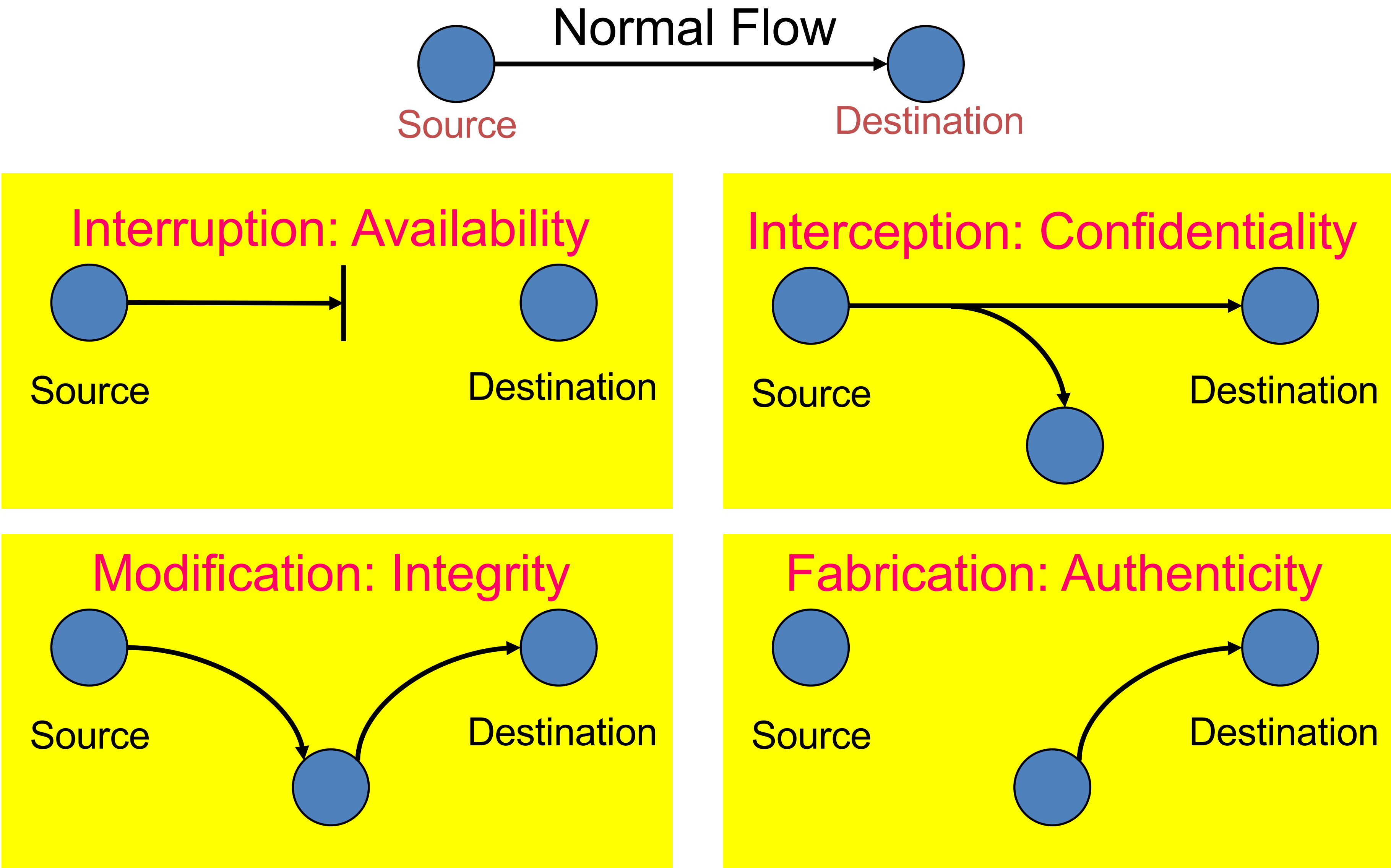
- New Problems in New Technologies
  - Sensors in Self-Driving Cars and Drones
  - Security of Deep Learning
  - Block Chain Pool Mining Attacks
  - Brain Hacking

Basic Cryptography

The Main Players



Attacks



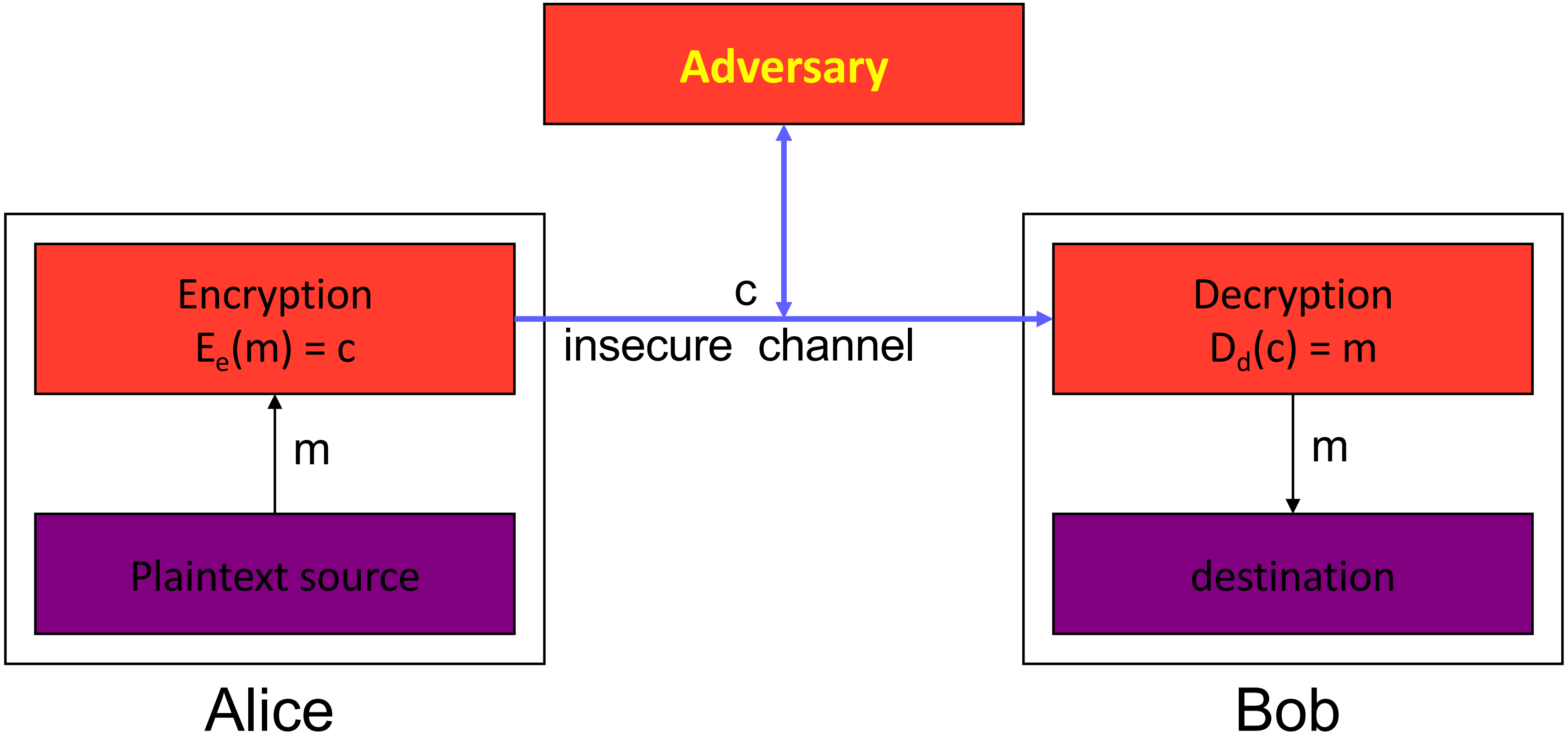
Normal Flow
Source
Destination
Interruption: Availability
Source
Destination
Interception: Confidentiality
Source
Destination
Modification: Integrity
Source
Destination
Fabrication: Authenticity
Source
Destination

Taxonomy of Attacks

- Passive attacks
  - Eavesdropping
  - Traffic analysis

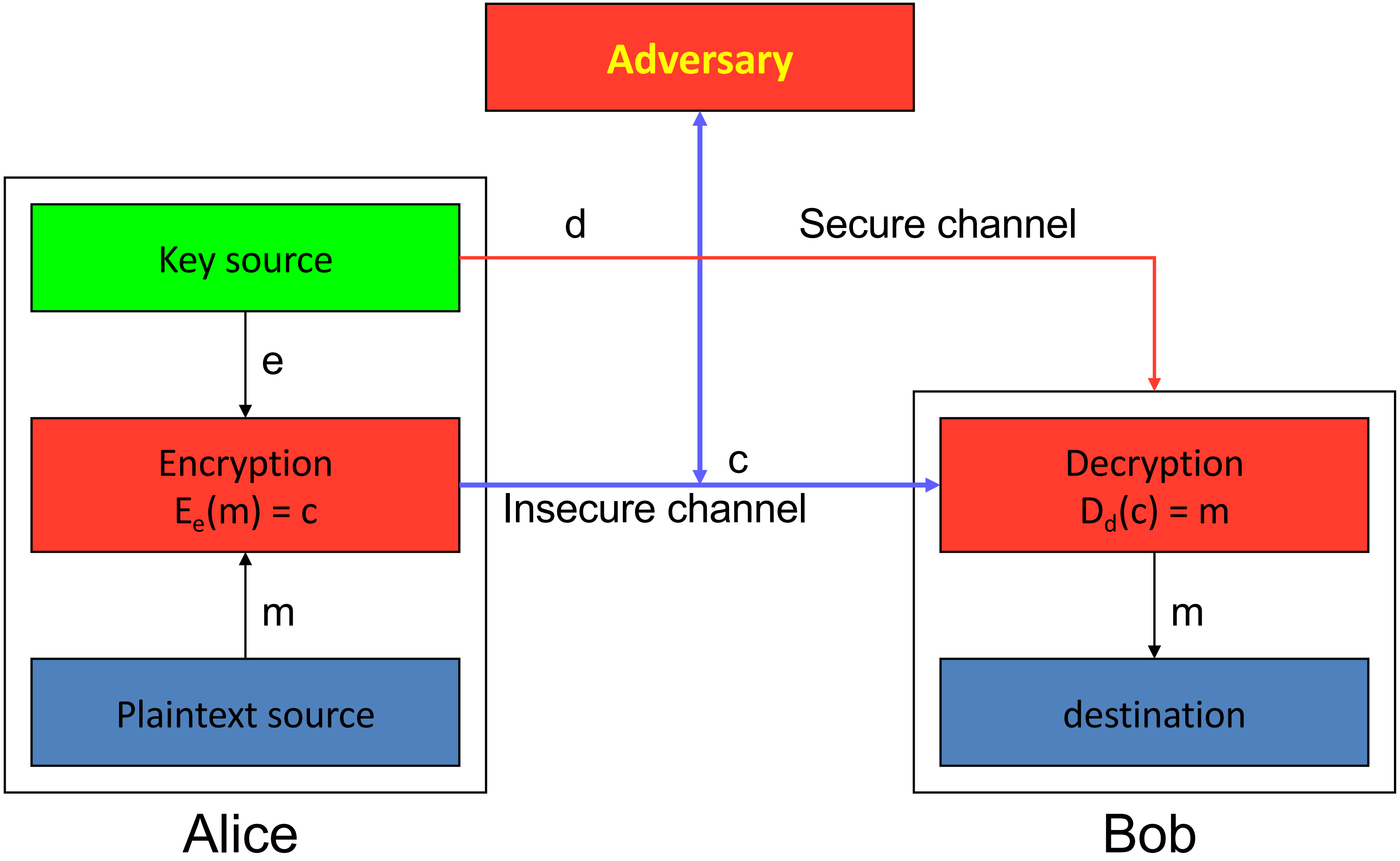
- Active attacks
  - Masquerade
  - Replay
  - Modification of message content
  - Denial of service

Encryption

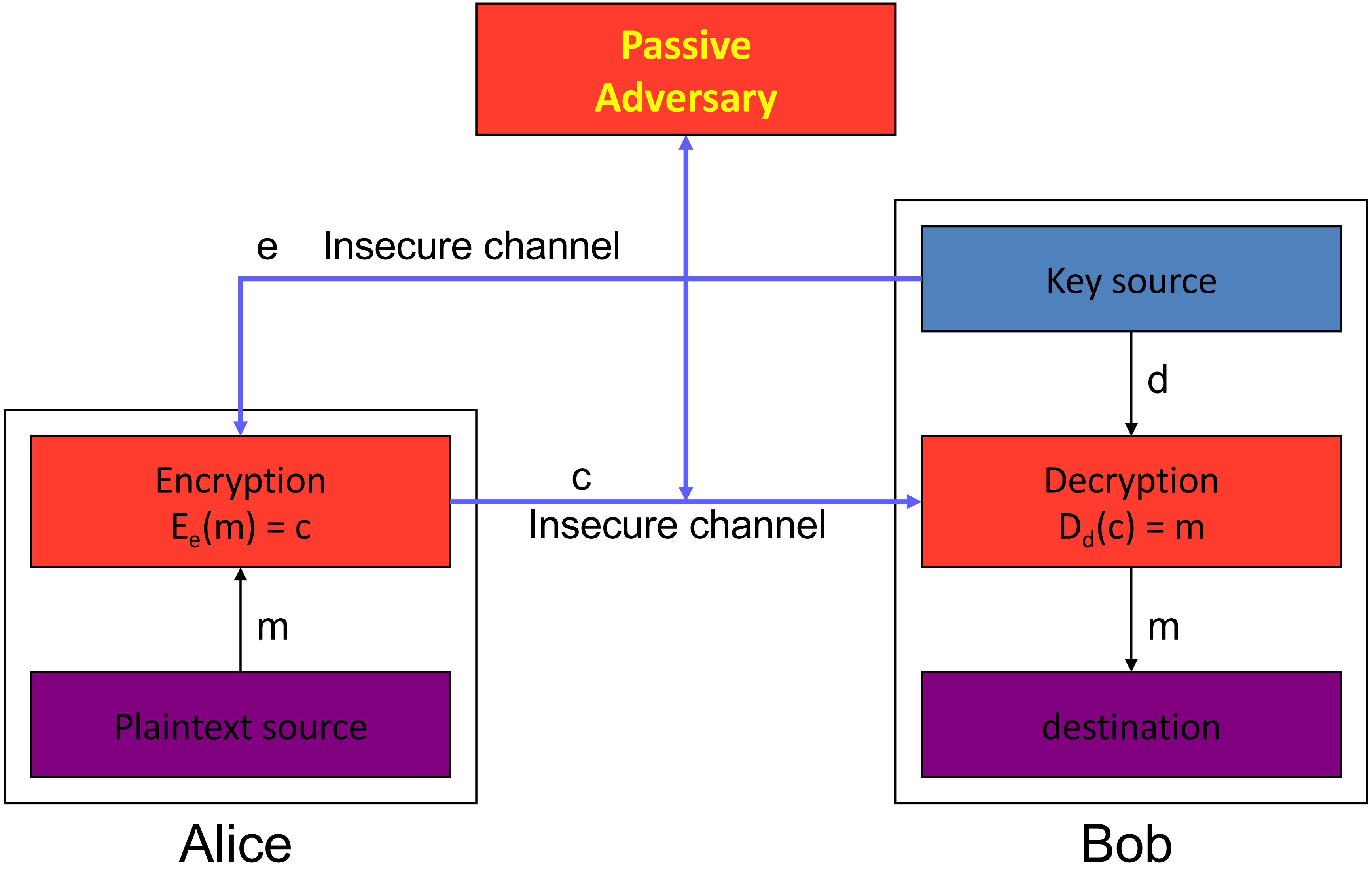


- Why do we use key?
  - Or why not use just a shared encryption function?

SKE with Secure channel

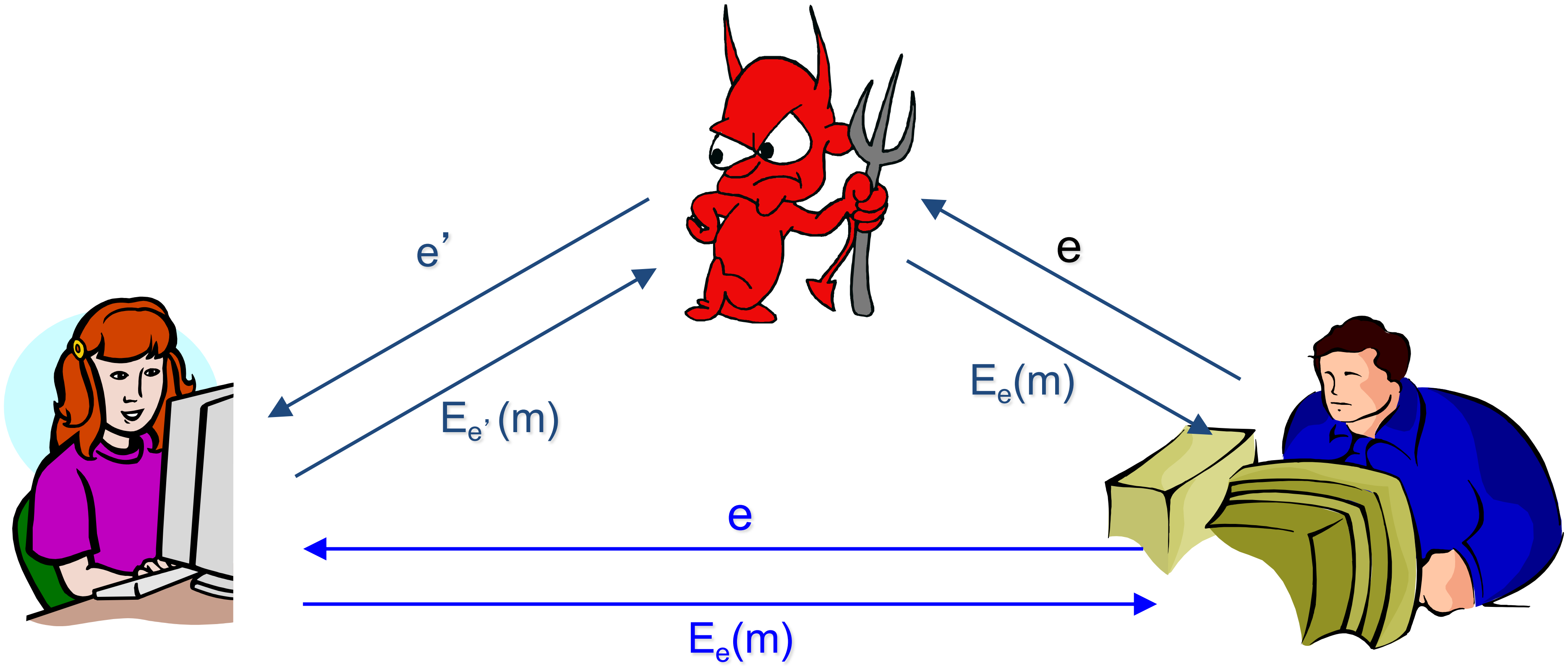


PKE with Insecure Channel



SysSec
System Security Lab

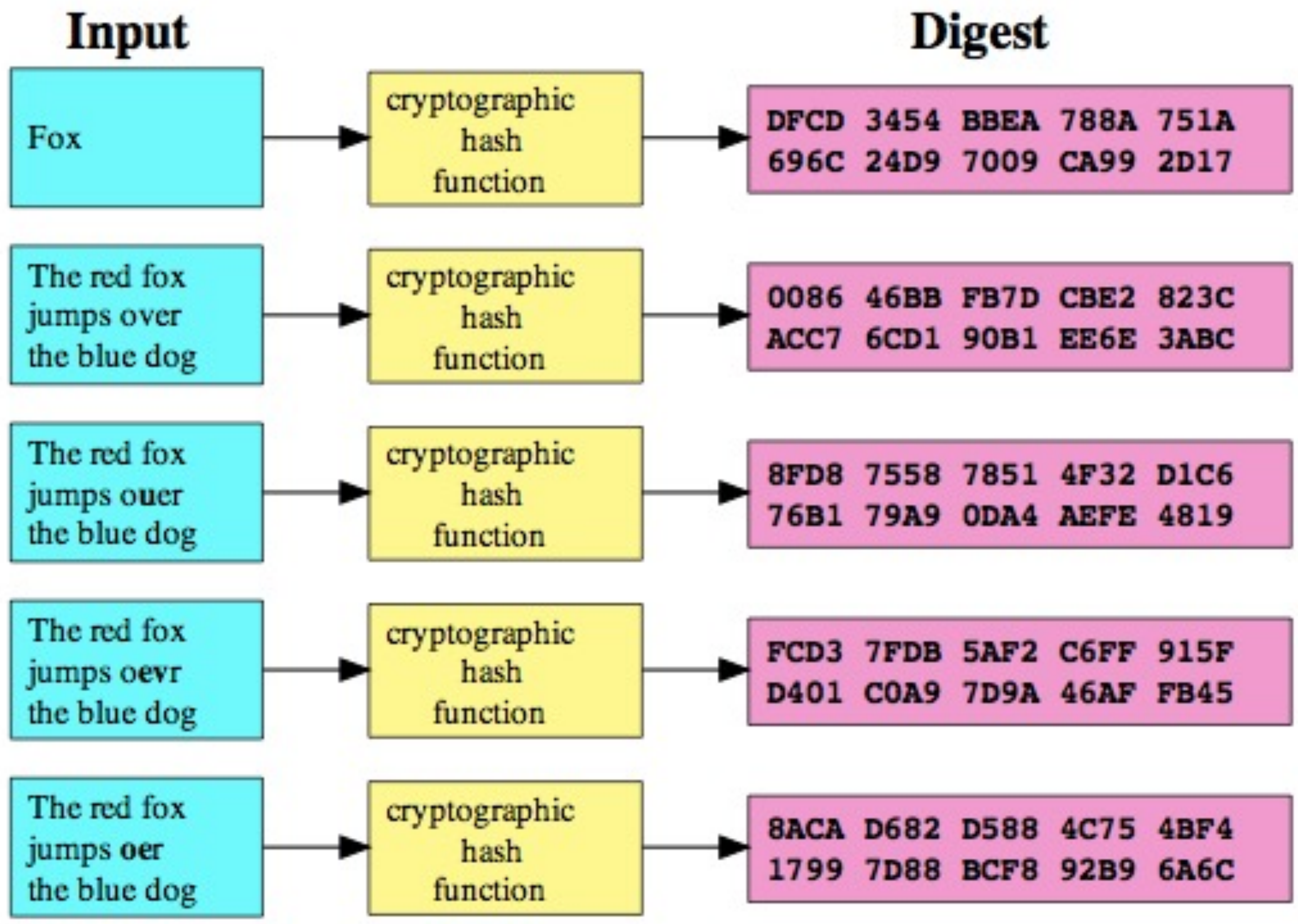
Public Key should be authentic!



Hash Function

- A hash function is a function h satisfying
  - $h:\{0, 1\}^* \rightarrow \{0, 1\}^k$ (Compression)
- A cryptographic hash function is a hash function satisfying
  - It is easy to compute y=h(x) (ease of computation)
  - For a given y, it is hard to find x' such that h(x')=y. (onewayness)
  - It is hard to find x and x' such that h(x)=h(x') (collision resistance)
- Examples: SHA-1, MD-5

How Random is the Hash function?



Applications of Hash Function

- File integrity

- Digital signature

  Sign = $S_{SK}(h(m))$

- Password verification

stored hash = h(password)

- File identifier
- Hash table
- Generating random numbers

Hash function and MAC

- A hash function is a function h
  - compression
  - ease of computation
  - Properties
    - » one-way: for a given y, find x' such that h(x') = y
    - » collision resistance: find x and x' such that h(x) = h(x')
  - Examples: SHA-1, MD-5

- MAC (message authentication codes)
  - both authentication and integrity
  - MAC is a family of functions h_k
    - » ease of computation (if k is known !!)
    - » compression, x is of arbitrary length, $h_k(x)$ has fixed length
    - » computation resistance
  - Example: HMAC

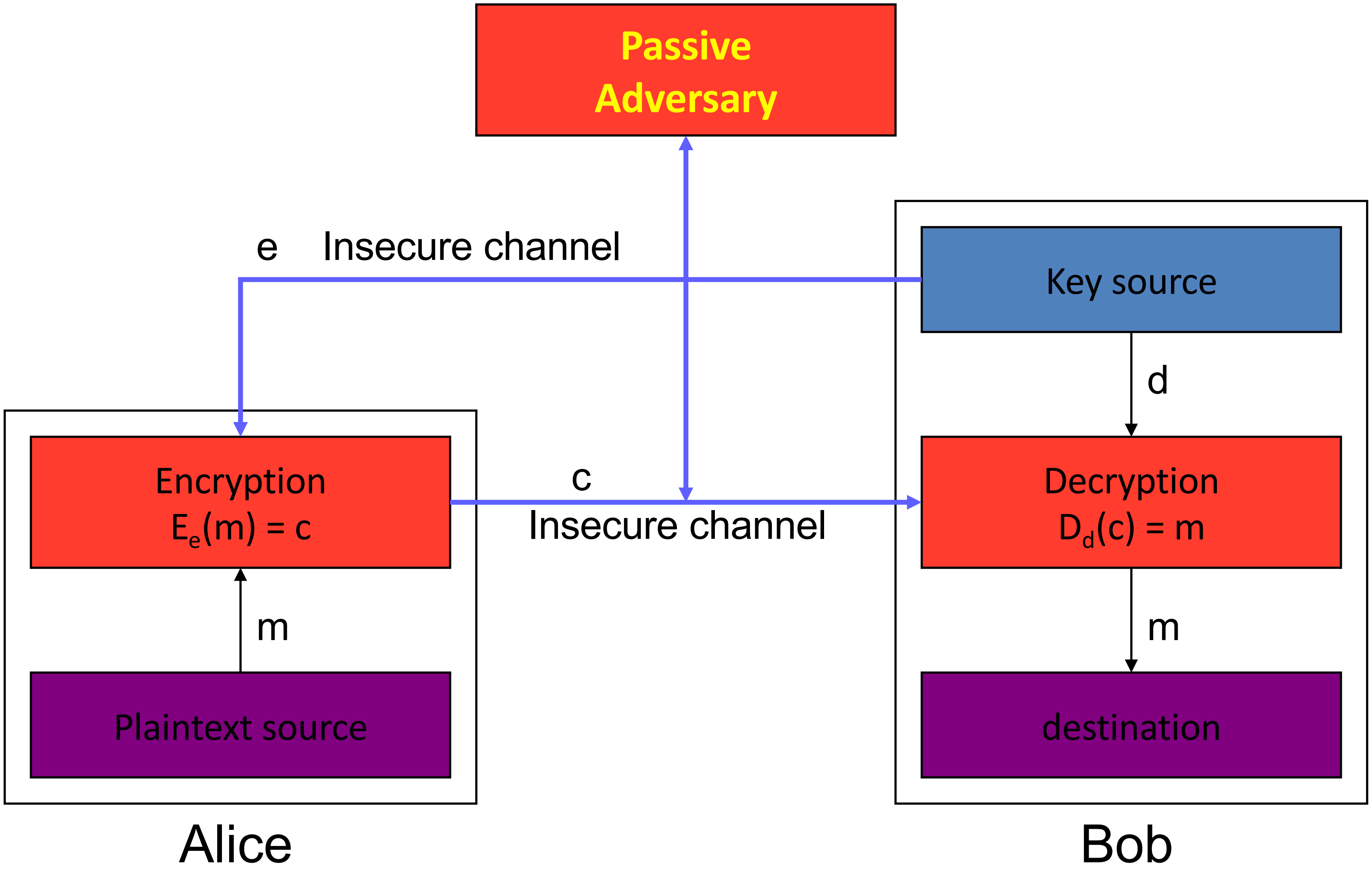
MAC construction from Hash

- Prefix
  - M=h(k||x)
  - appending y and deducing h(k||x||y) form h(k||x) without knowing k
- Suffix
  - M=h(x||k)
  - possible a birthday attack, an adversary that can choose x can construct x' for which h(x)=h(x') in $O(2^{n/2})$
- STATE OF THE ART: HMAC (RFC 2104)
  - $HMAC(x)=h(k||p_1||h(k|| p_2||x))$, p1 and p2 are padding
  - The outer hash operates on an input of two blocks
  - Provably secure

How to use MAC?

- A & B share a secret key k
- A sends the message x and the MAC $M \leftarrow H_k(x)$
- B receives x and M from A
- B computes $H_k(x)$ with received M
- B checks if $M = H_k(x)$

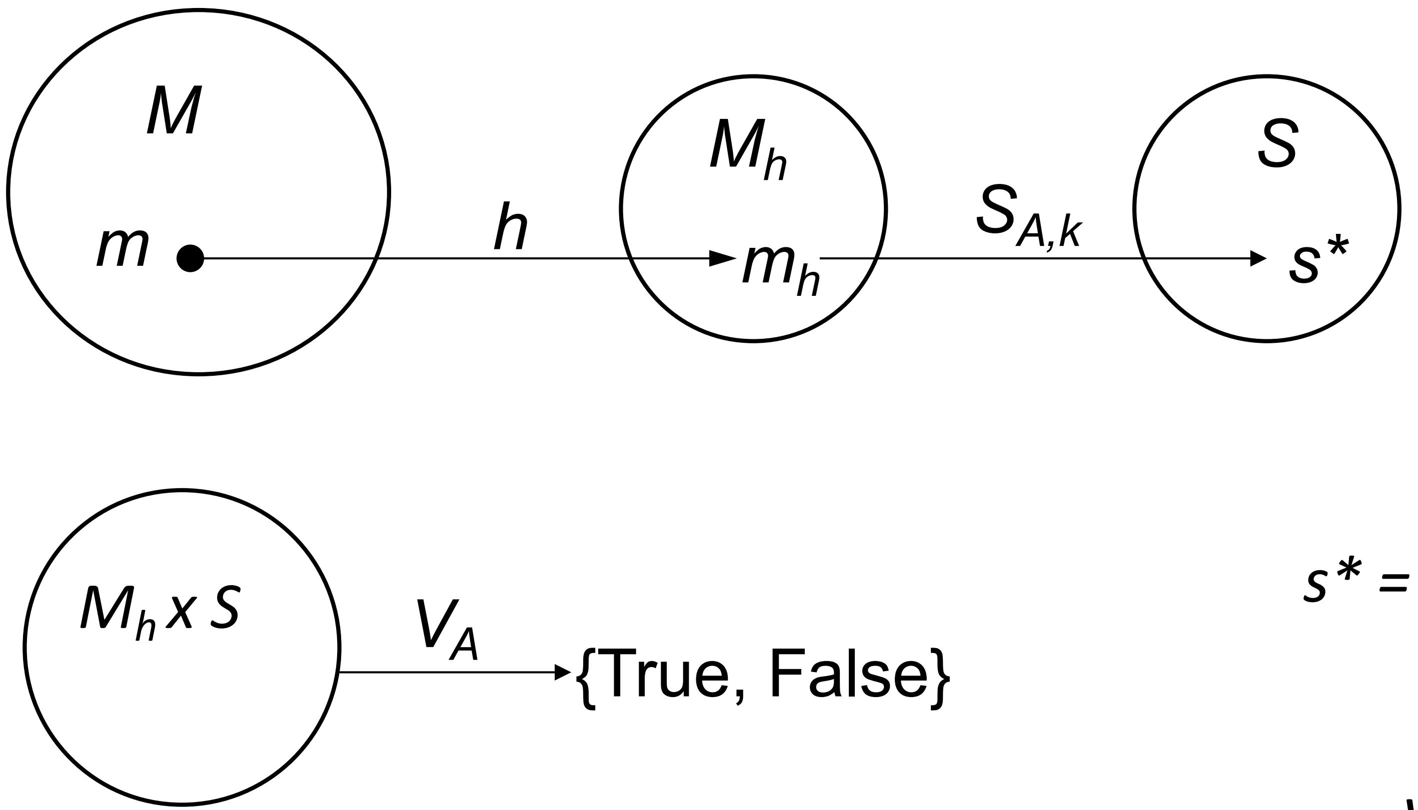
PKE with Insecure Channel



Digital Signature

- Integrity
- Authentication
- Non-repudiation

Digital Signature with Appendix



$s^* = S_{A,k}(m_h)$

$u = V_A(m_h, s^*)$

Authentication

- How to prove your identity?
  - Prove that you know a secret information
- When key K is shared between A and Server
  - A ➔ S: $HMAC_K(M)$ where M can provide freshness
  - Why freshness?
- Digital signature?
  - A ➔ S: $Sig_{SK}(M)$ where M can provide freshness
- Comparison?

Encryption and Authentication

- $E_K(M)$

- Redundancy-then-Encrypt: $E_K(M, R(M))$
- Hash-then-Encrypt: $E_K(M, h(M))$
- Hash and Encrypt: $E_K(M), h(M)$
- MAC and Encrypt: $E_{h1(K)}(M), HMAC_{h2(K)}(M)$
- MAC-then-Encrypt: $E_{h1(K)}(M, HMAC_{h2(K)}(M))$

Challenge-response authentication

- Alice is identified by a *secret* she possesses
  - *Bob* needs to know that Alice does indeed possess this secret
  - *Alice* provides ***response*** to a time-variant ***challenge***
  - Response depends on ***both*** secret and challenge

- Using
  - Symmetric encryption
  - One way functions

Challenge Response using SKE

- Alice and Bob share a key *K*
- Taxonomy
  - ***Unidirectional*** authentication using ***timestamps***
  - ***Unidirectional*** authentication using ***random numbers***
  - ***Mutual*** authentication using ***random numbers***
- Unilateral authentication using timestamps
  - Alice $\rightarrow$ Bob: $E_K(t_A, B)$
  - Bob decrypts and verified that timestamp is OK
  - Parameter *B* prevents replay of same message in B $\rightarrow$ A direction

Challenge Response using SKE

- Unilateral authentication using random numbers
  - Bob → Alice: r_b
  - Alice → Bob: $E_K(r_b, B)$
  - Bob checks to see if r_b is the one it sent out
    - » Also checks "B" – prevents reflection attack
  - r_b must be ***non-repeating***
- Mutual authentication using random numbers
  - Bob → Alice: r_b
  - Alice → Bob: $E_K(r_a, r_b, B)$
  - Bob → Alice: $E_K(r_a, r_b)$
  - Alice checks that r_a, r_b are the ones used earlier

Challenge-response using OWF

- Instead of encryption, used keyed MAC h_K
- Check: compute MAC from *known quantities*, and check with message
- SKID3
  - Bob $\rightarrow$ Alice: r_b
  - Alice $\rightarrow$ Bob: r_a, $h_K(r_a, r_b, B)$
  - Bob $\rightarrow$ Alice: $h_K(r_a, r_b, A)$

Key Establishment, Management

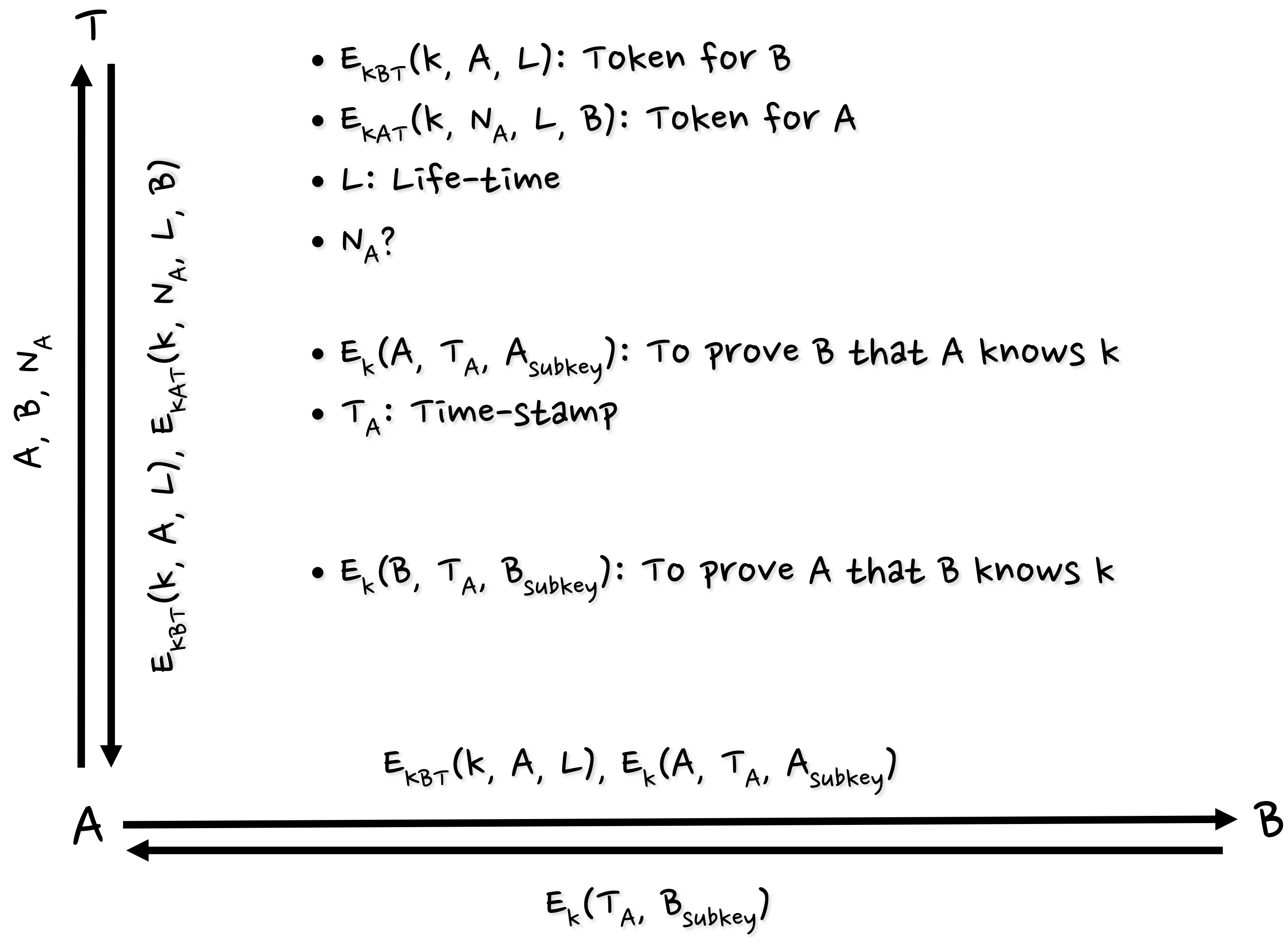
- Key establishment
  - Process to whereby a shared secret key becomes available to two or more parties
  - Subdivided into key agreement and key transport.

- Key management
  - The set of processes and mechanisms which support key establishment
  - The maintenance of ongoing keying relationships between parties

Kerberos vs. PKI vs. IBE

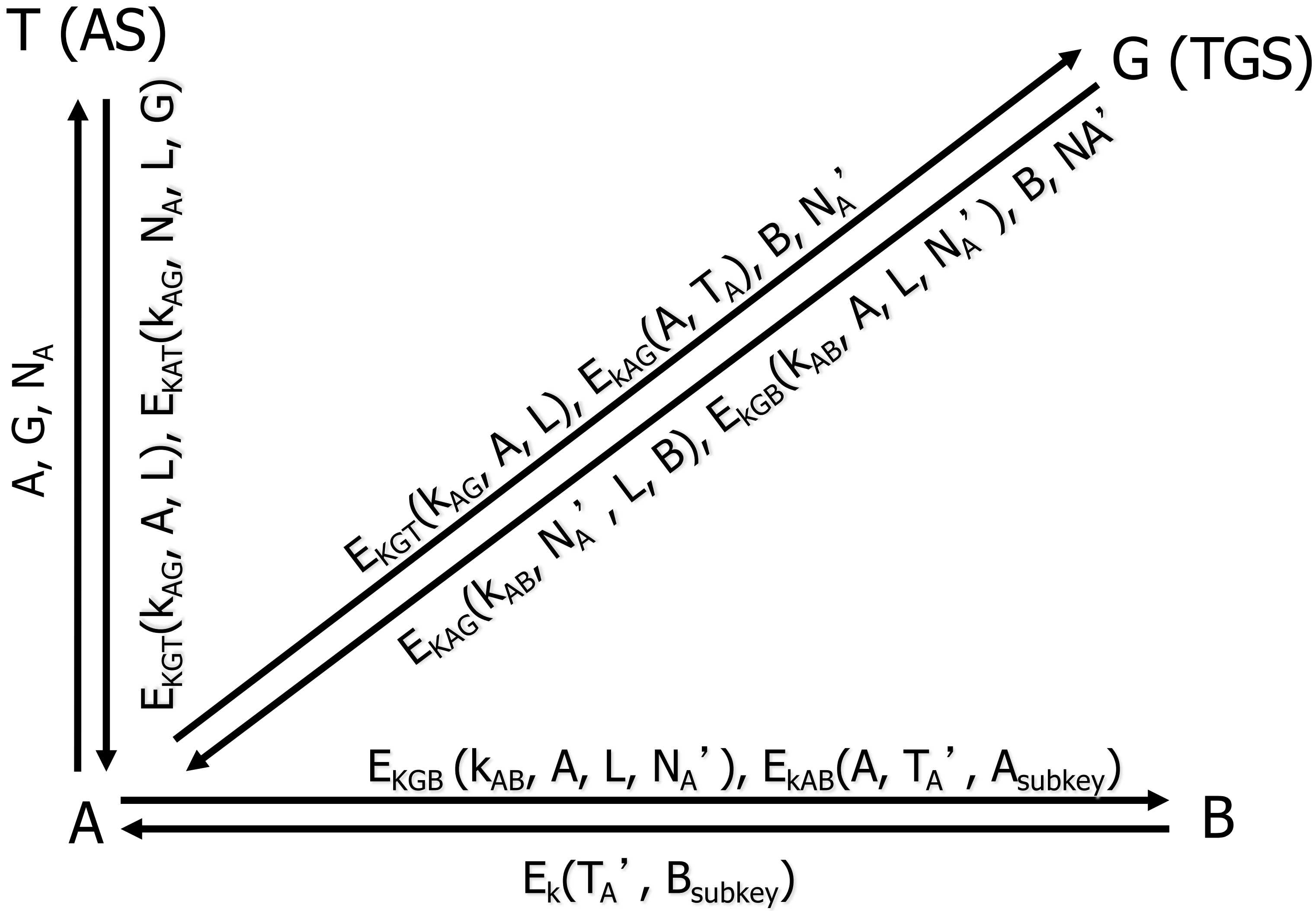
- Still debating ☺
- Let’s see one by one!

Kerberos (cnt.)



- $E_{KBT}(k, A, L)$: Token for B
- $E_{KAT}(k, N_A, L, B)$: Token for A
- L: Life-time
- N_A?
- $E_k(A, T_A, A_{subkey})$: To prove B that A knows k
- T_A: Time-stamp
- $E_k(B, T_A, B_{subkey})$: To prove A that B knows k

Kerberos (Scalable)



Public Key Certificate

- Public-key certificates are a vehicle
  - public keys may be stored, distributed or forwarded over unsecured media
- The objective
  - make one entity's public key available to others such that its authenticity and validity are verifiable.
- A public-key certificate is a data structure
  - data part
    - » cleartext data including a public key and a string identifying the party (subject entity) to be associated therewith.
  - signature part
    - » digital signature of a certification authority over the data part
    - » binding the subject entity's identity to the specified public key.

CA

- a trusted third party whose signature on the certificate vouches for the authenticity of the public key bound to the subject entity
  - The significance of this binding must be provided by additional means, such as an attribute certificate or policy statement.
- the subject entity must be a unique name within the system (distinguished name)
- The CA requires its own signature key pair, the authentic public key.
- Can be off-line!

ID-based Cryptography

- No public key
- Public key = ID (email, name, etc.)
- PKG
  - Private key generation center
  - $SK_{ID} = PKG_{S}(ID)$
  - PKG's public key is public.
  - distributes private key associated with the ID
- Encryption: $C = E_{ID}(M)$
- Decryption: $D_{SK}(C) = M$

Discussion (PKI vs. Kerberos vs. IBE)

- On-line vs. off-line TTP
  - Implication?
- Non-reputation?
- Revocation?
- Scalability?
- Trust issue?

Questions?

- Yongdae Kim
  - email: yongdaek@kaist.ac.kr
  - Home: http://syssec.kaist.ac.kr/~yongdaek
  - Facebook: https://www.facebook.com/y0ngdaek
  - Twitter: https://twitter.com/yongdaek
  - Google "Yongdae Kim"