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Network Security Intro

Redes de Computadores

2021/22

Pedro Brandão

References

- Slides are by Mark Stamp "Information Security: Principles and Practice" 2nd edition (Wiley 2011).
- Some other slides from Dr Lawrie Brown (UNSW@ADFA) for "Computer Security: Principles and Practice", 1/e, by William Stallings and Lawrie Brown
- With adaptations/additions by Pedro Brandão

Driving questions…

- *How to secure protocols?*
- *What are the key objectives of securing protocols?*
- *Are security protocols hard or brittle?*
- *How to use crypto operations to provide those objectives?*
- *What is the path of a packet in the kernel?*
- *Can change it in that path?*

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Crypto refresh

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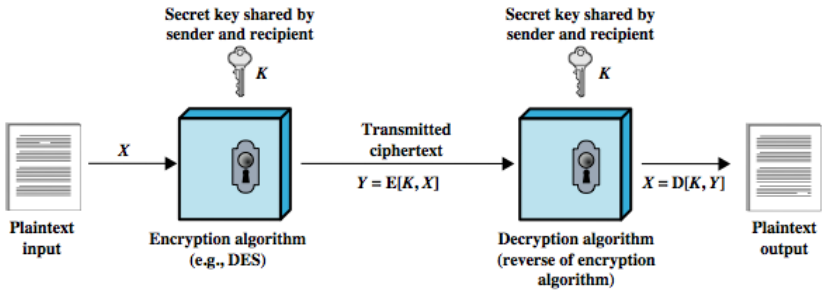
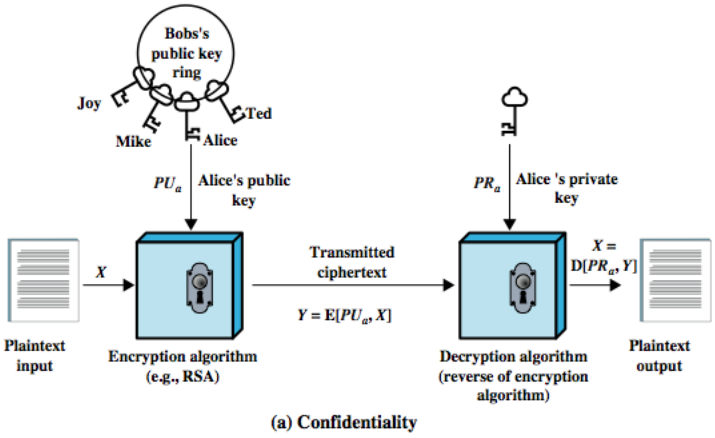
How to Speak Crypto

- A cipher or cryptosystem is used to encrypt the plaintext
- The result of encryption is ciphertext
- We decrypt ciphertext to recover plaintext
- A key is used to configure a cryptosystem
- A symmetric key cryptosystem uses the same key to encrypt as to decrypt
- A public key cryptosystem uses a public key to encrypt and a private key to decrypt
- Nonce == number used once

Symmetric key

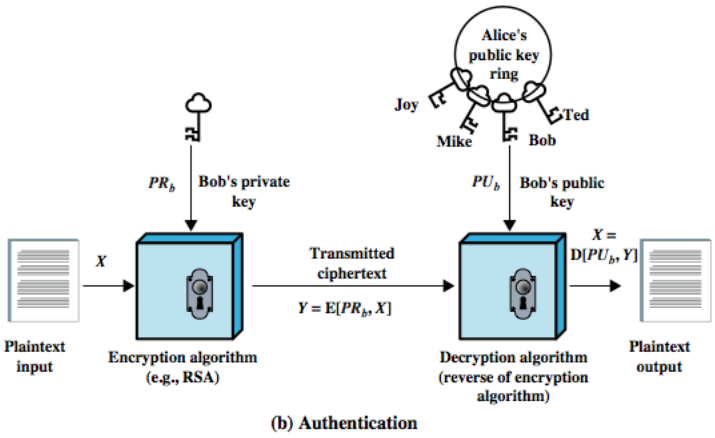


Public Key Encryption



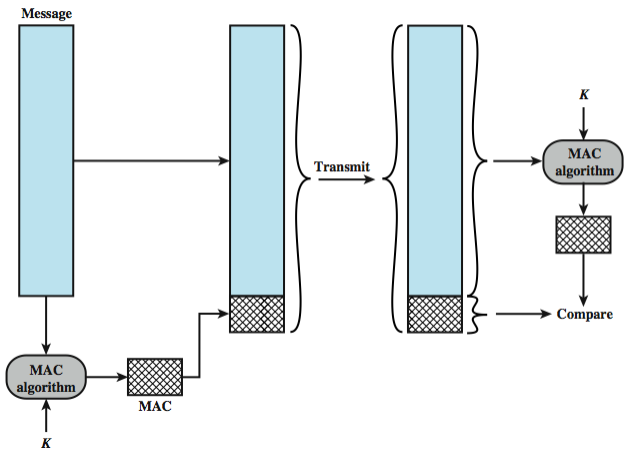
(a) Confidentiality

Public Key Authentication

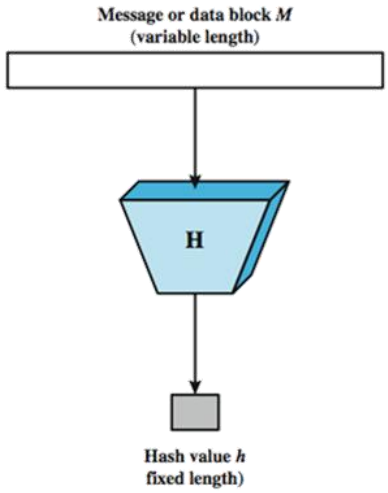


(b) Authentication

Message Authentication Codes



Secure Hash Functions



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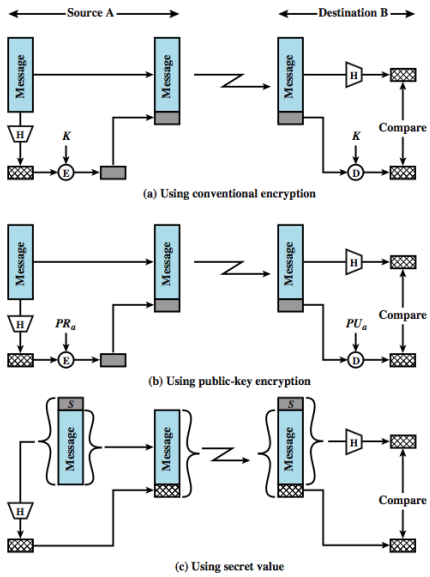
Message Auth



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Internet security protocols

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Protocols

- Protocol flaws can be very subtle
- Several well-known security protocols have significant flaws
  - Including WEP, GSM, and even IPsec, SSL (POODLE and its extension to TLS, DROWN, ROBOT)
- Implementation errors can occur
  - Such as IE implementation of SSL (CVE-2002-0862), OpenSSL (HeartBleed, FREAK, HEIST)
- Not easy to get protocols right…

More attacks on TLS

Security Protocols - Features

- Authentication
  - Of machines, users, i.e. communication end-points
  - Mutual
- Confidentiality
  - Exchanged communications are non-readable/understandable by others
  - Flow of information is confidential
    - Usually hard to achieve
- Crypto integrity
  - Data handled has not been tampered with
    - Discard tampered data
- Non-repudiation
  - Communicators may not denying sending messages
    - Message is associated with peer

Ideal Security Protocol

- Satisfies security requirements
  - Requirements must be precise
- Efficient
  - Small computational requirement
  - Small bandwidth usage, network delays…
- Robust
  - Works when attacker tries to break it
  - Works even if environment changes
- Easy to use & implement, flexible…
- Difficult to satisfy all of these!

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Simple Security Protocols

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Secure Entry to NSA

1. Insert badge into reader
2. Enter PIN
3. Correct PIN?
   - **Yes?** Enter
   - **No?** Get shot by security guard

ATM Machine Protocol

1. Insert ATM card
2. Enter PIN
3. Correct PIN?
   - **Yes?** Conduct your transaction(s)
   - **No?** Machine (eventually) eats card

Identify Friend or Foe (IFF)

Russian
SU-34

Homs

USAF
F-35
K

2. E(N,K)

1. N

Hama
K

SU in the Middle

USAF
F-35
K

3. N

4. E(N,K)

Homs

2. N

5. E(N,K)

Russian
SU-34

6. E(N,K)

1. N

Hama
K

Authentication Protocols

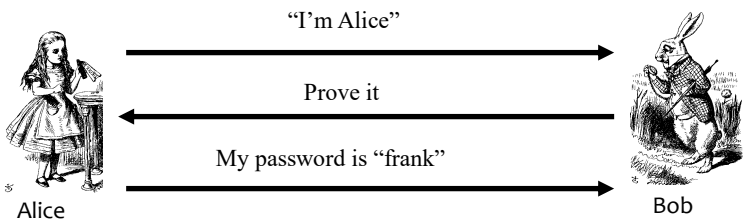
Authentication

- Alice must prove her identity to Bob
  - Alice and Bob can be humans or **computers**
- May also require Bob to prove he's Bob (mutual authentication)
- Probably need to establish a **session key**
- May have other requirements, such as
  - Use public keys
  - Use symmetric keys
  - Use hash functions
  - Anonymity, plausible deniability, etc., etc.

Authentication

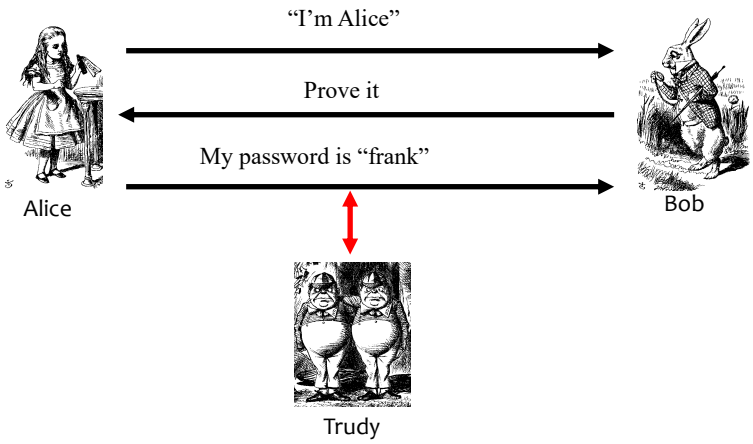
- Authentication on a stand-alone computer is relatively simple
  - Hash password with salt, etc.
  - "Secure path," attacks on authentication software, keystroke logging, etc., are issues
- Authentication over a network is challenging
  - Attacker can passively observe messages
  - Attacker can replay messages
  - Active attacks possible (insert, delete, change)

Simple Authentication

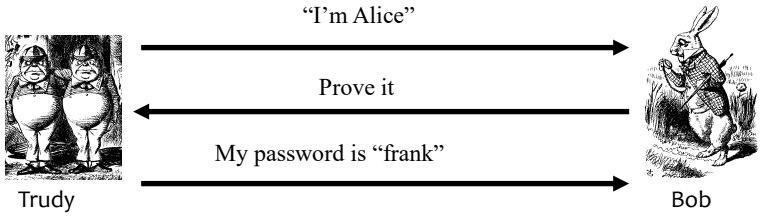


- Simple and may be OK for standalone system
- But insecure for networked system
  - Subject to a replay attack (next 2 slides)
  - Also, Bob must know Alice's password

Authentication Attack

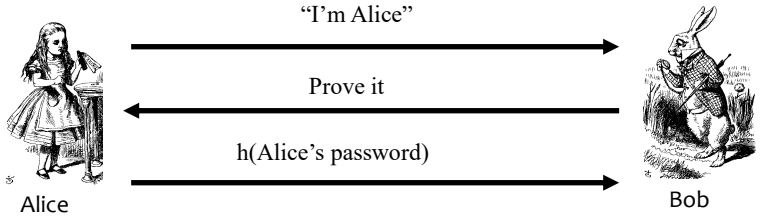


Authentication Attack



- This is an example of a replay attack
- How can we prevent a replay?

Better Authentication



- Better since it hides Alice's password
  - From both Bob and Trudy
- Subject to replay?
  - YES

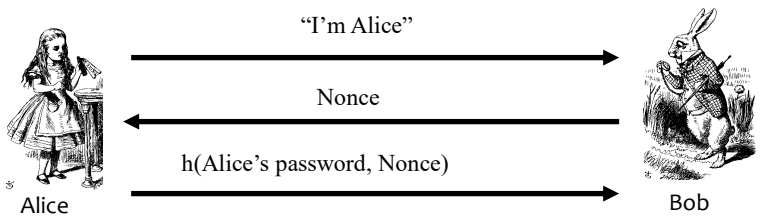
Challenge-Response

- To prevent replay, use challenge-response
  - Goal is to ensure "freshness"
- Suppose Bob wants to authenticate Alice
  - Challenge sent from Bob to Alice
- Challenge is chosen so that
  - Replay is not possible
  - Only Alice can provide the correct response
  - Bob can verify the response

Nonce

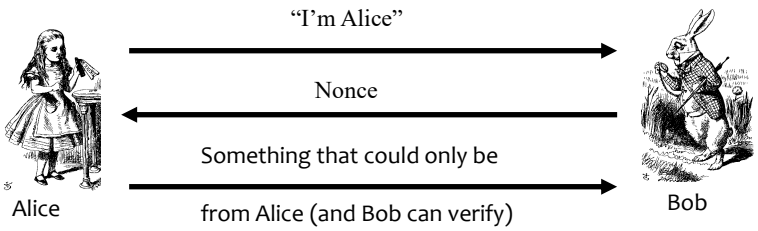
- To ensure freshness, can employ a nonce
  - Nonce == number used once
- What to use for nonces?
  - That is, what is the challenge?
- What should Alice do with the nonce?
  - That is, how to compute the response?
- How can Bob verify the response?
- Should we rely on passwords or keys?

Challenge-Response



- Nonce is the challenge
- The hash is the response
- Nonce prevents replay, ensures freshness
- Password is something Alice knows
- Bob must know Alice's pwd to verify

Generic Challenge-Response



- In practice, how to achieve this?
- Hashed pwd works…
- Encryption (using keys) is better here (Why?)

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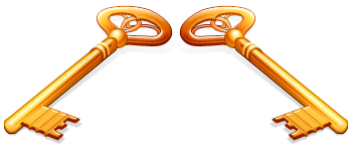

Symmetric Keys

Authentication protocols

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Symmetric Key Notation

- Encrypt plaintext P with key K

  `C = E(P,K)`

- Decrypt ciphertext C with key K

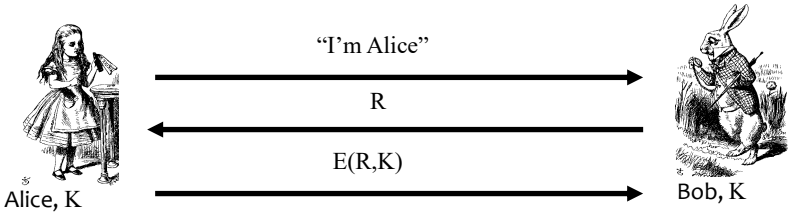
  `P = D(C,K)`

- Here, we are concerned with attacks on protocols, **not** attacks on crypto
  - We assume crypto algorithms secure

Authentication: Symmetric Key

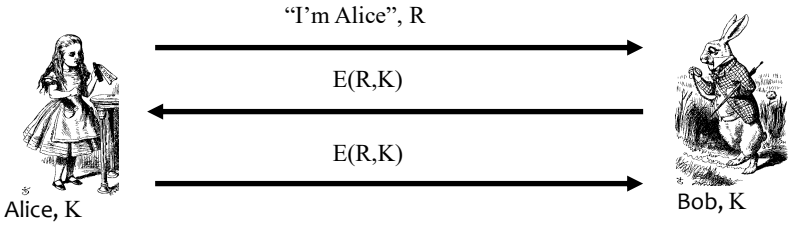
- Alice and Bob share symmetric key K
- Key K known only to Alice and Bob
- Authenticate by proving knowledge of shared symmetric key
- How to accomplish this?
  - Must not reveal key, must not allow replay (or other) attack, must be verifiable, …

Authentication with Symmetric Key



- Secure method for Bob to authenticate Alice
- Alice **does not** authenticate Bob
- So, can we achieve mutual authentication?

Mutual Authentication?

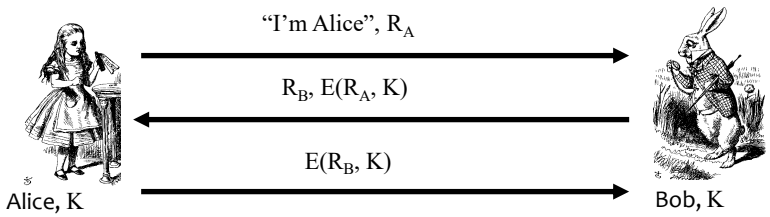


- What's wrong with this picture?
- "Alice" could be Trudy (or anybody else)!

Mutual Authentication

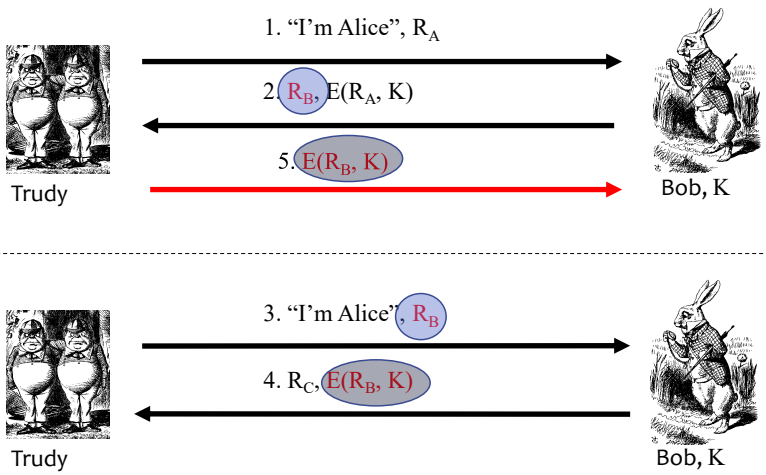
- Since we have a secure one-way authentication protocol…
- The obvious thing to do is to use the protocol twice
  - Once for Bob to authenticate Alice
  - Once for Alice to authenticate Bob
- This has got to work…

Mutual Authentication



- This provides mutual authentication…
- … or does it?

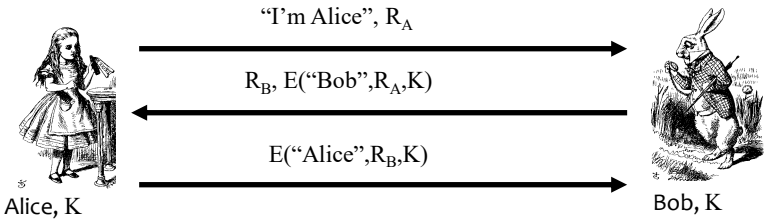
Mutual Authentication Attack



Mutual Authentication

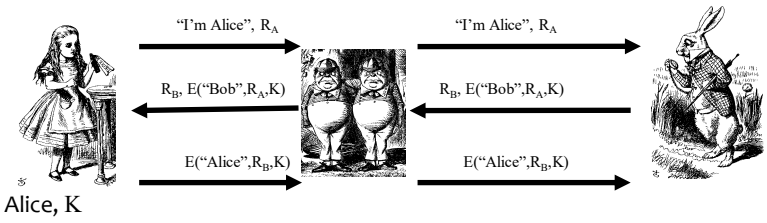
- Our one-way authentication protocol is not secure for mutual authentication
  - Protocols are subtle!
  - The "obvious" thing may not be secure
- Also, if assumptions or environment change, protocol may not be secure
  - This is a common source of security failure
  - For example, Internet protocols

Symmetric Key Mutual Authentication



- *Do these "insignificant" changes help?*
  - Yes!

Symmetric Key Mutual Authentication



- *Is this MiTM?*
- *What else is needed to thwart this?*
  - Session key

Public Keys

Authentication protocols

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Public Key Notation

- Encrypt M with Alice's public key: $\{M\}_{Alice}$
- Sign M with Alice's private key: $[M]_{Alice}$
- Then
  - $[\{M\}_{Alice}]_{Alice} = M$
  - $\{[M]_{Alice}\}_{Alice} = M$
- **Anybody** can use Alice's **public key**
- Only **Alice** can use her **private key**

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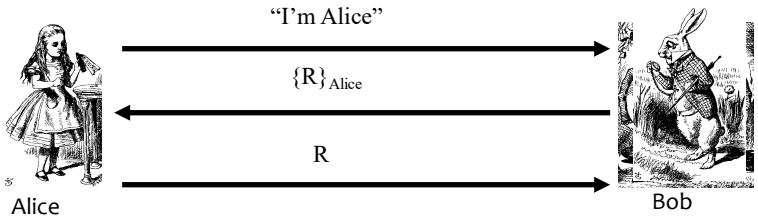
Public Key Authentication



- Is this secure?
- Trudy can get Alice to decrypt anything!
  - So, should have two key pairs

Public Key Authentication

- Is this secure?
- Trudy can get Alice to sign anything!
  - Same as previous — should have two key pairs

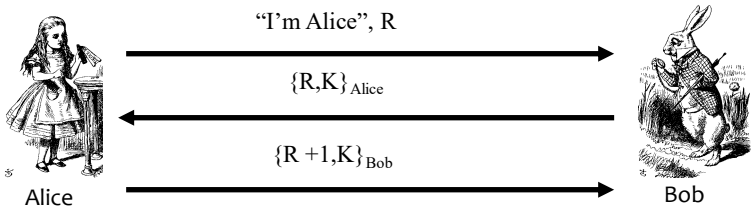
Public Keys

- Generally, a bad idea to use the same key pair for encryption and signing
- Instead, should have…
  - … one key pair for encryption/decryption…
  - … and a different key pair for signing/verifying signatures

Session Key

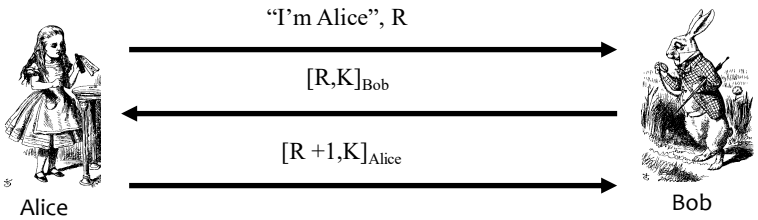
- Usually, a **session key** is required
  - I.e., a symmetric key for a particular session
  - Used for confidentiality and/or integrity
- How to authenticate and establish a session key (i.e., shared symmetric key)?
  - When authentication completed, want Alice and Bob to share a session key
  - Trudy cannot break the authentication…
  - … and Trudy cannot determine the session key

Authentication & Session Key



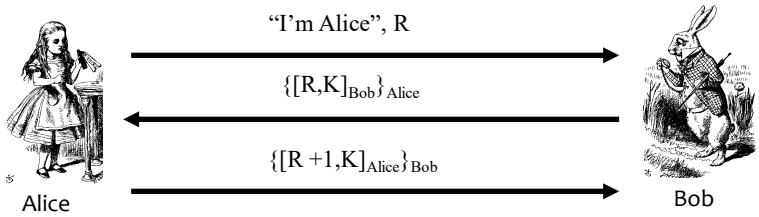
- Is this secure?
  - Alice is authenticated and session key is secure
  - Alice's "nonce", R, useless to authenticate Bob
  - The key K is acting as Bob's nonce to Alice
- No mutual authentication

Public Key Authentication and Session Key



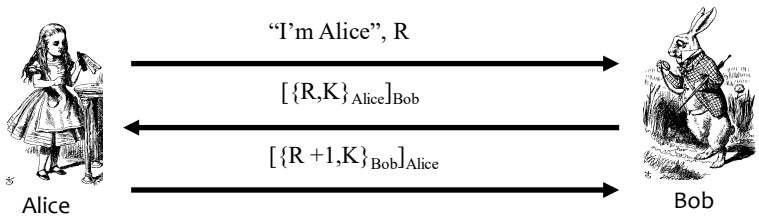
- Is this secure?
  - Mutual authentication (good), but…
  - … session key is not secret (very bad)

Public Key Authentication and Session Key



- Is this secure?
- Seems to be OK
- Mutual authentication and session key!

Public Key Authentication and Session Key



- Is this secure?
- Seems to be OK
  - Anyone can see $\{R,K\}_{Alice}$ and $\{R+1,K\}_{Bob}$

Iptables and netfilter

Firewalling

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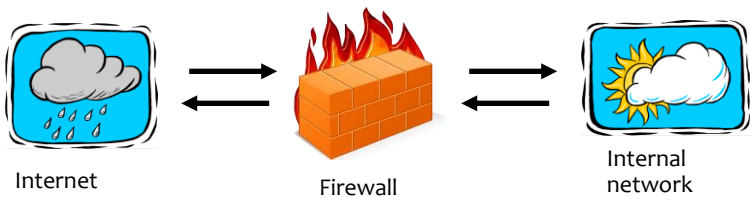
Firewalls

- Firewall must determine what to let in to internal network and/or what to let out
- Access control for the network



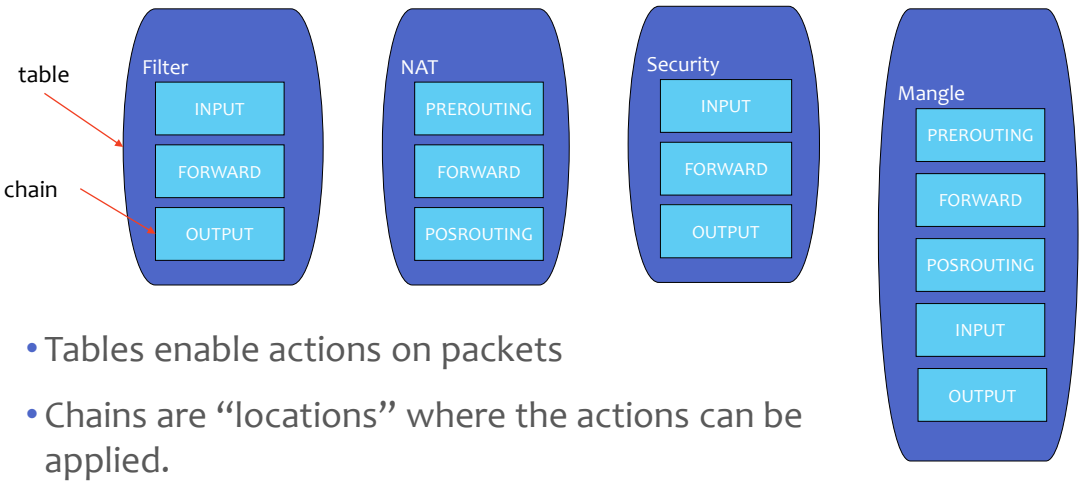
Iptables and netfilter

$> man iptables

`administration tool for IPv4/IPv6 packet filtering and NAT`

- From netfilter.org
  - "provides packet filtering software for the Linux 2.4.x and later kernel series. The netfilter project is commonly associated with iptables and its successor nftables."
  - `nftables` replaces the popular `{ip,ip6,arp,eb}tables`.

Tables contain chains



- Tables enable actions on packets
- Chains are "locations" where the actions can be applied.

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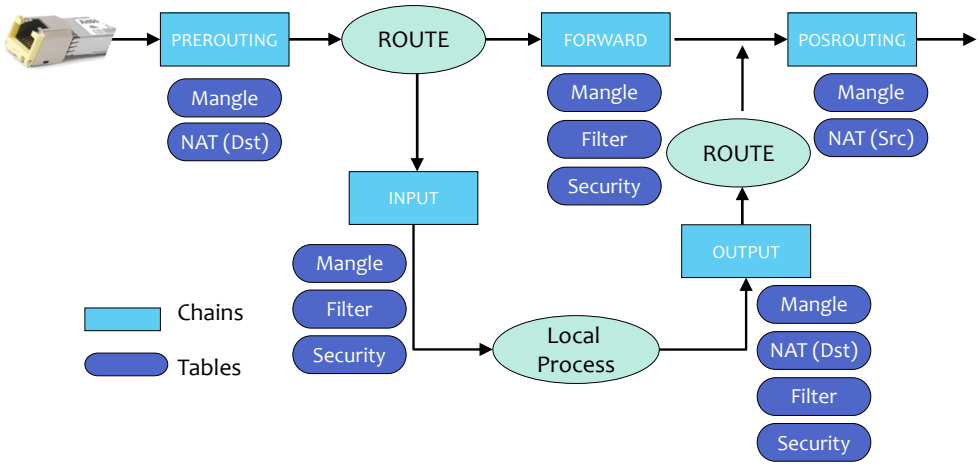
iptables – path of an IP packet on Netfilter



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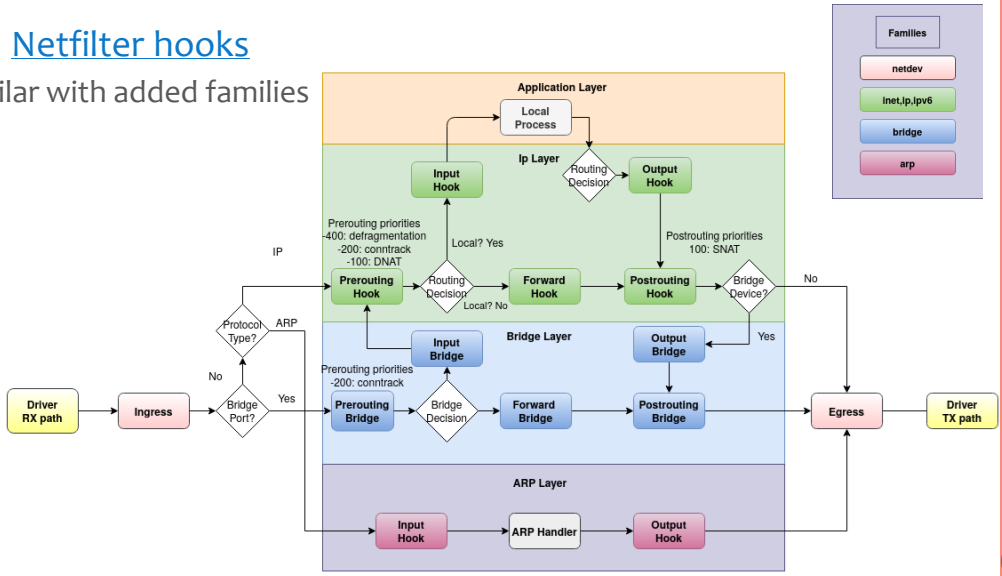
nftables view

- From Netfilter hooks
  - Similar with added families



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Iptables and nftables examples

- iptables:

```
## Change source addresses to 1.2.3.4.
iptables -t nat -A POSTROUTING -o eth0 -j SNAT --to 1.2.3.4
```

table: nat — chain: POSTROUTING — target: SNAT

- nftables:

```
## Change source addresses to 1.2.3.4.
nft add rule ip nat POSTROUTING oifname "eth0" counter snat to 1.2.3.4
```

table: nat — chain: POSTROUTING — target: snat

See Moving from iptables to nftables

Summary

- Secure protocols, what are they good for…
  - Authentication protocols
  - Symmetric, public key
- iptables and path of a packet in netFilter

Homework

1. Review slides

2. Read from Tanenbaum
   - Section 8.7.1 –Authentication Based on a Shared Secret Key

3. Answer questions at Moodle

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End of Network Security Intro