Outline

- Chapter 19: Security (cont)
- A Method for Obtaining Digital Signatures and Public-Key Cryptosystems Ronald L. Rivest, Adi Shamir, and Leonard M. Adleman. Communications of the ACM 21,2 (Feb. 1978)
  - RSA Algorithm – First practical public key crypto system
- Authentication in Distributed Systems: Theory and Practice, Butler Lampson, Martin Abadi, Michael Burrows, Edward Wobber
  - Butler Lampson (MSR) - He was one of the designers of the SDS 940 time-sharing system, the Alto personal distributed computing system, the Xerox 9700 laser printer, two-phase commit protocols, the Autonet LAN, and several programming languages
  - Martin Abadi (Bell Labs)
  - Michael Burrows, Edward Wobber (DEC/Compaq/HP SRC)

Encryption

- Properties of good encryption technique:
  - Relatively simple for authorized users to encrypt and decrypt data.
  - Encryption scheme depends not on the secrecy of the algorithm but on a parameter of the algorithm called the encryption key.
  - Extremely difficult for an intruder to determine the encryption key.

Strength

- Strength of crypto system depends on the strengths of the keys
- Computers get faster – keys have to become harder to keep up
- If it takes more effort to break a code than is worth, it is okay
  - Transferring money from my bank to my credit card and Citibank transferring billions of dollars with another bank should not have the same key strength

Encryption methods

- Symmetric cryptography
  - Sender and receiver know the secret key (apriori)
    - Fast encryption, but key exchange should happen outside the system
- Asymmetric cryptography
  - Each person maintains two keys, public and private
    - M ≡ PrivateKey(PublicKey(M))
    - M ≡ PublicKey (PrivateKey(M))
  - Public part is available to anyone, private part is only known to the sender
  - E.g. Pretty Good Privacy (PGP), RSA

My Public Key

```
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: PGPfreeware 7.0.3 for non-commercial use <http://www.pgp.com>

mQGiBDqtLPwRBADnG0+9IkDvI8t/3wdL3CSO4DytEH0NjrNwAYYIaewp3MklsxkP
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9Xgv4qxKEA==
=Pv5O
-----END PGP PUBLIC KEY BLOCK-----
```

Public Key Infrastructure (PKI)

- Process of issuing, delivering, managing and revoking public keys
- E.g. Secure Socket Layer (SSL)
  - Client C connects to Server S
    1. C requests server certificate from S
    2. S sends server certificate with Spublic to C
    3. C verifies validity of Spublic
    4. C generate symmetric key for session
    5. C encrypts Csymmetric using Spublic
    6. C transmits Csymmetric(data) and Spublic(Csymmetric) to S

Authentication

- Identification verification process
  - E.g. kerberos certificates, digital certificates, smart cards

- Used to grant resources to authorized users

RSA

- Named after Rivest, Shamir and Adleman
  - Only receiver receives message:
    - Encode message using receivers public key
  - Only sender could've sent the message
    - Encode message using sender's private key
  - Only sender could've sent the message and only receiver can read the message
    - Encode message using receivers public key and then encode using our private key

Practical Public Key Cryptosystem

1. Decrypt(Encrypt(Message)) = Message
2. Encrypt() and Decrypt() are easy to compute
3. Encrypt() does not reveal Decrypt()
4. Encrypt(Decrypt(Message)) = Message

- Function satisfying 1-3: Trap-door one-way function
  - One way: easy to compute in one direction, difficult in the other direction
  - Trap-door: Inverse functions are easy to compute once certain private “trap-door” information is known.

Signature

- Encrypt using private key of sender. Anyone can decrypt using the public key of sender to verify signature

```
-----BEGIN PGP SIGNED MESSAGE-----
Hash: SHA1

Hello world!!
-----BEGIN PGP SIGNATURE-----
Version: PGPfreeware 7.0.3 for non-commercial use
   <http://www.pgp.com>

iQA/AwUBOq8LO5VO3RVVn3orEQLFZwCdGi9AWvlhollaYmr9TPvtdbK
   oe20AoLLr
vbJ8SgkIZ73lCy6SXDi91osd
=L3Sh
-----END PGP SIGNATURE-----
```

Privacy

- Encrypt with receivers public key

```
-----BEGIN PGP MESSAGE-----
Version: PGPfreeware 7.0.3 for non-commercial use <http://www.pgp.com>

qANQR1DBwU4D30m79rqmjHMQB/4q1mu3IP8AsMBYSUW6udXZnF0/LVL51eYzVnAW
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5ECybmVrHQ==
=S9ph
-----END PGP MESSAGE-----
```

Algorithm

- To break their algorithm requires that you factor a large prime
  - Computationally very hard. Can’t be “proven” yet
  - With present technology, 512 bit key takes a few months to factor using “super computers”, 1024 takes a long time and 2048 takes a very long time
  - Takes 2 seconds to generate a 2048 bit key on a 933 Mhz Pentium, 1 seconds in a 2.4 GHz Xeon
  - Algorithm has remained secure for the past ~20 years
  - One of the most successful public key system

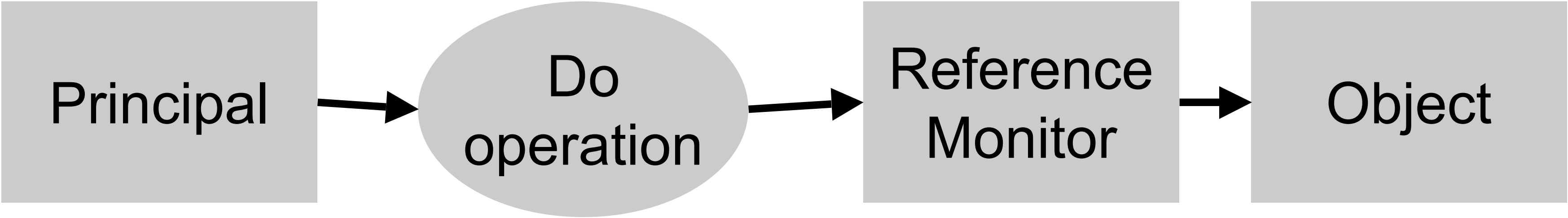
Authentication

- Method for obtaining the source of the request
  - Who said this?
- Interpreting the access rule – authorization
  - Who is trusted to access this?
  - Access control list (ACL)
- Easier in central servers because the server knows all the sources

Distributed authentication

- Autonomy: Request might come through a number of untrusted nodes
- Size: Multiple authentication sources
- Heterogeneity: Different methods of connecting
- Fault-tolerance: Parts of the system may be broken

Access Control Model

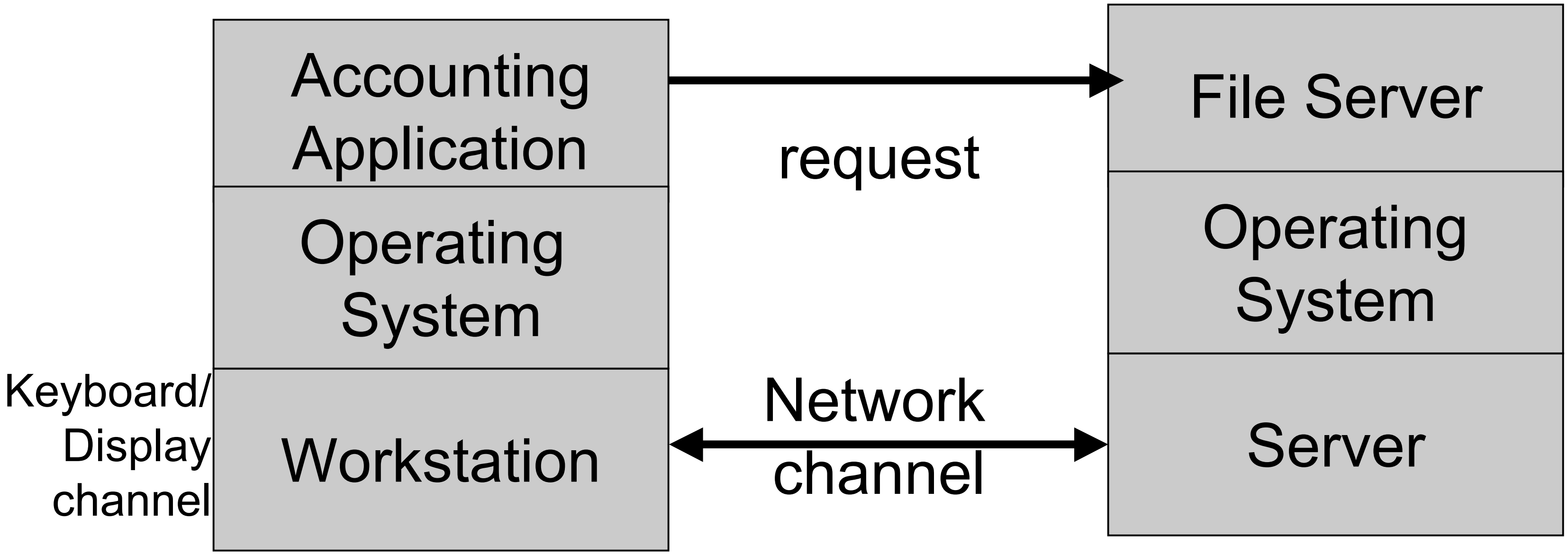


- Principal: source for requests
- Requests to perform operations on objects
- Reference monitor: a guard for each object that examines each request for the object and decides whether to grant it
- Objects: Resource such as files, processes ..

Trusted Computing Base

- A small amount of software and hardware that security depends upon
  - You have to trust something
- Possible to obtain trusted statements from untrusted source
  - end-to-end argument
- TCB typically includes:
  - Operating system
  - Hardware
  - Encryption mechanisms
  - Algorithms for authentication and authorization

Example scenario



- One user, two machines, two operating systems, two subsystems, and two channels
- All communication over channels (no direct comm.)

Encryption channels

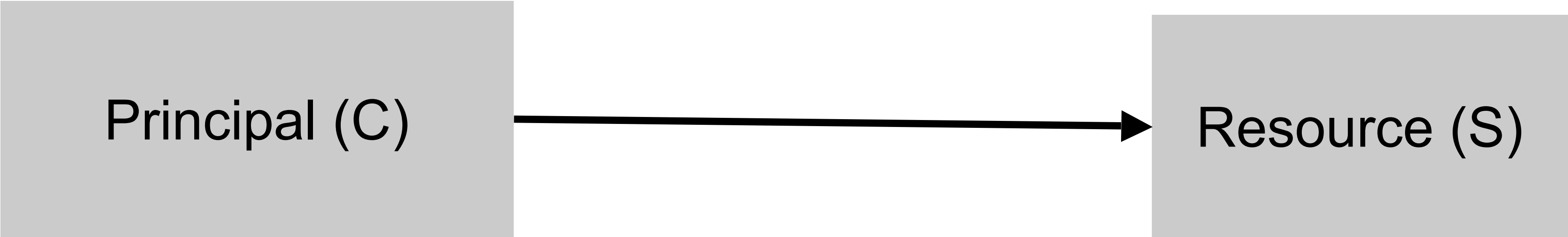
- Shared vs public key cryptography
  - – Shared is fast
  - – Public key systems are easy to manage
  - – Hybrids offer best of both worlds (e.g. SSL)

- Broadcast encryption channels
  - – Public key channel is broadcast channel: you can send a message without knowing who will receive it
  - – Shows how you can implement broadcast channel using shared keys
- Node-to-node secure channels

Principals with names

- When requests arrive on a channel it is granted only if the channel speaks for one of the principals on the ACL
  - Push: sender collects A’s credentials and presents them when needed
  - Pull: receiver looks up A in some database to get credentials for A

Man in the middle attach

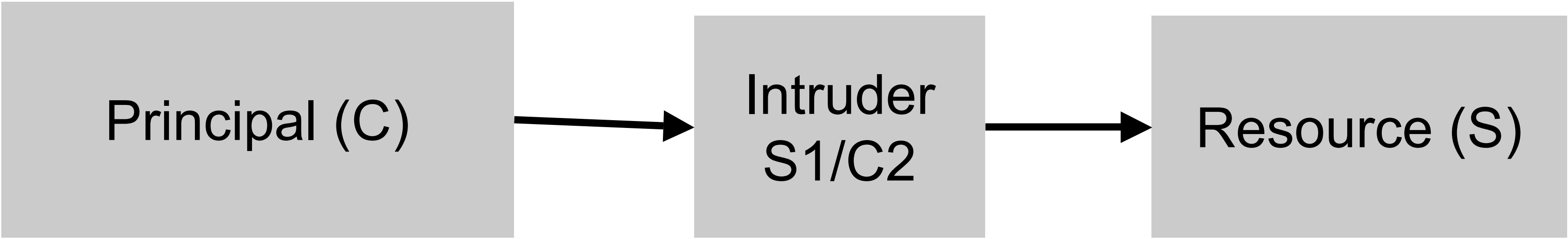


Principal (C)

Resource (S)

1. C requests server certificate from S
2. S sends server certificate with Spublic to C
3. C verifies validity of Spublic
4. C generate symmetric key for session
5. C encrypts Csymmetric using Spublic
6. C transmits Csymmetric(data) and Spublic(Csymmetric) to S

Man in the middle attach



- C requests server certificate from S
- S sends server certificate with Spublic to C
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- Certification authorities

Certification Authority

- Difficult to make system highly available and highly secure
  - Leave CA offline, endorse certificates with long timeout
  - Online agent highly available, countersign with shorter timeout
  - Cache while both timeouts fresh
  - Invalidation at cache granularity
- Simple Certification Authority
  - CA speaks for A and is trusted when it says that C speaks for A
    - Everyone trusts CA to speak for named principal
    - Everyone knows public key of CA
- Pathnames and Multiple authorities
  - Decentralized authority, parents cannot unconditionally speak for children

Groups

- Each principal speaks for the group
- Group membership certificates
  - Impossible to tell the membership
- Alternate approach is to distribute certificates to all principals
  - Revocation?

Roles and programs

- Role that a user play; a normal user or sysadmin?
- ACL may distinguish the role
- Delegation:
  - Users delegate to compute server

Auditing

- Formal proof for every access control decision