Key Management
CS 239
Computer Security
February 13, 2006

Outline

- Properties of keys
- Key management
- Key servers
  - Kerberos
- Certificates

Introduction

- It doesn't matter how strong your encryption algorithm is
- Or how secure your protocol is
- If the opponents can get hold of your keys, your security is gone
- Proper use of keys is crucial to security in computing systems

Properties of Keys

- Length
- Randomness
- Lifetime

Key Length

- If your cryptographic algorithm is otherwise perfect, its strength depends on key length
- Since the only attack is a brute force attempt to discover the key
- The longer the key, the more brute force required

Are There Real Costs for Key Length?

- Clearly, more bits is more secure
- Why not a whole lot of key bits, then?
- Much encryption done in hardware
  - More bits in hardware costs more
- Software encryption slows down as you add more bits, too
  - Public key cryptography costs are highly dependent on key length

Key Randomness

- Brute force attacks assume you chose your key at random
- If the attacker can get any knowledge about your mechanism of choosing a key, he can substantially reduce brute force costs
- How good is your random number generator?

Generating Random Keys

- Well, don't use `rand()`
- The closer the method chosen approaches true randomness, the better
- But, generally, don't want to rely on exotic hardware
- True randomness is not essential
  - Need same statistical properties
  - And non-reproducibility

Cryptographic Methods

- Start with a random number
- Use a cryptographic hash on it
- If the cryptographic hash is a good one, the new number looks pretty random
- Produce new keys by hashing old ones
- Depends on strength of hash algorithm
- Falls apart if any key is ever broken
  - Doesn't have *perfect forward secrecy*

Random Noise

- Observe an event that is likely to be random
- Assign bit values to possible outcomes
- Record or generate them as needed
- Sources:
  - Physical processes (cosmic rays, etc.)
  - Real world processes (variations in disk drive delay, keystroke delays, etc.)

Don't Go Crazy on Randomness

- Make sure it's non-reproducible
  - So attackers can't play it back
- Make sure there aren't obvious patterns
- Attacking truly unknown patterns in fairly random numbers is extremely challenging
  - They'll probably mug you, instead

Key Lifetime

- If a good key's so hard to find,
  - Why every change it?
- How long should one keep using a given key?

Why Change Keys?

- Long-lived keys more likely to be compromised
- The longer a key lives, the more data is exposed if it's compromised
- The longer a key lives, the more resources opponents can (and will) devote to breaking it
- The more a key is used, the easier the cryptanalysis on it
- A secret that cannot be readily changed should be regarded as a vulnerability

Practicalities of Key Lifetimes

- In some cases, changing keys is inconvenient
  - E.g., encryption of data files
- Keys used for specific communications sessions should be changed often
  - E.g., new key for each phone call
- Keys used for key distribution can't be changed too often

Destroying Old Keys

- Never keep a key around longer than necessary
  - Gives opponents more opportunities
- Destroy keys securely
  - For computers, remember that information may be in multiple places
    - Caches, virtual memory pages, freed file blocks, stack frames, etc.

Key Management

- Choosing long, random keys doesn't do you any good if your clerk is selling them for $10 a pop at the back door
- Or if you keep a plaintext list of them on a computer on the net whose root password is "root"
- Proper key management is crucial

Desirable Properties in a Key Management System

- Secure
- Fast
- Low overhead for users
- Scaleable
- Adaptable
  - Encryption algorithms
  - Applications
  - Key lengths

Users and Keys

- Where are a user's keys kept?
- Permanently on the user's machine?
  - What happens if the machine is cracked?
- But people can't remember random(ish) keys
  - Hash keys from passwords/passphrases?
- Keep keys on smart cards?
- Get them from key servers?

Security of Key Servers

- The key server is the cracker's holy grail
  - If they break the key server, everything else goes with it
- What can you do to protect it?

Security Measures for Key Servers

- Don't run anything else on the machine
- Use extraordinary care in setting it up and administering it
- Watch it carefully
- Use a key server that stores as few keys permanently as possible
- Use a key server that handles revocation and security problems well

Kerberos

- Probably the most widely used and well-known key server
- Originally developed at MIT
  - As part of Project Athena
- Uses trusted third parties
  - And symmetric cryptography
- Provides authentication in key service

The Kerberos Model

- Clients and servers sit on the network
- Clients want to interact securely with servers
  - Using a fresh key for each session
- Kerberos' job is to distribute keys to ensure that security
- Scalability is a concern

Obtaining a Key Through Kerberos

- The client needs to get a key to give to the server and use himself
- He obtains the key from a *ticket-granting server*
  - Essentially, a server who hands out keys to talk to other servers
- But the ticket-granting server needs authentication of the client
- Which is obtained from the Kerberos server

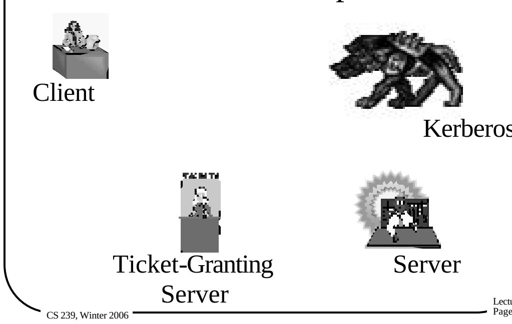
What's the Point of the Ticket-Granting Server?

- Scalability
  - Most requests for keys for servers go to ticket-granting server
  - There can be lots of them
- And issues of trust
  - Different ticket-granting servers can work with different servers and clients
  - So not everyone needs to trust one ticket-granting server

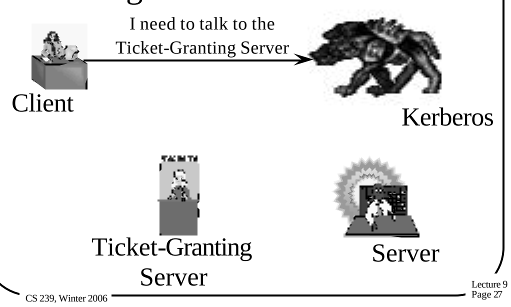
Players in the Kerberos Protocol

- The client
- The server
- The Ticket-Granting Service - someone the server trusts to authenticate the clients
- The Kerberos Server - someone everyone trusts

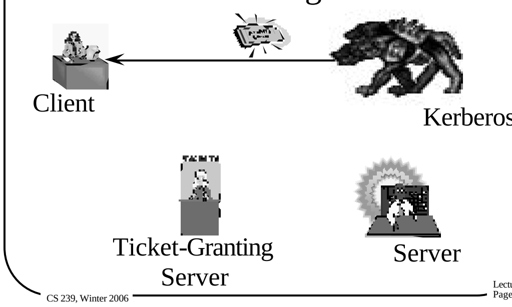
Kerberos Participants



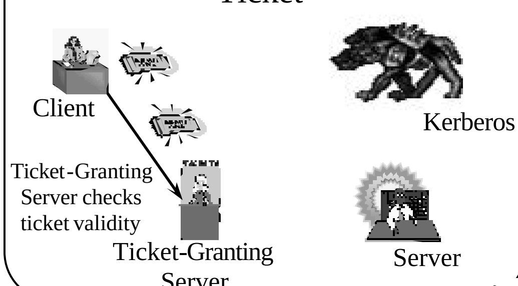
Client Requests a Ticket-Granting Ticket From Kerberos



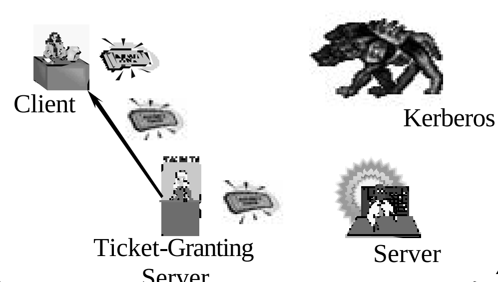
Kerberos Sends the Client a Ticket-Granting Ticket



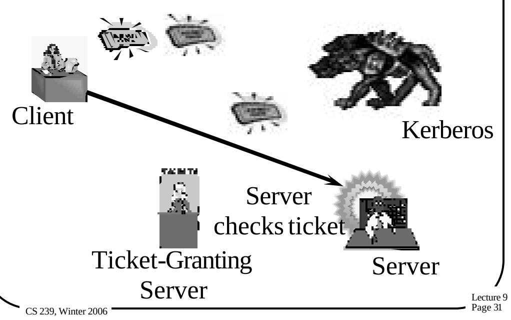
Client Asks TGS for a Server Ticket



TGS Sends Ticket to Client



Client Requests Service



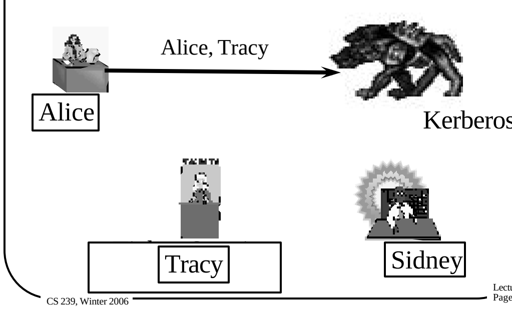
Tickets and Authenticators

- A Kerberos **ticket** is used to pass information to a server securely
- An **authenticator** is an additional credential passed along with the ticket
  - Used to pass timestamp information about lifetime of a key

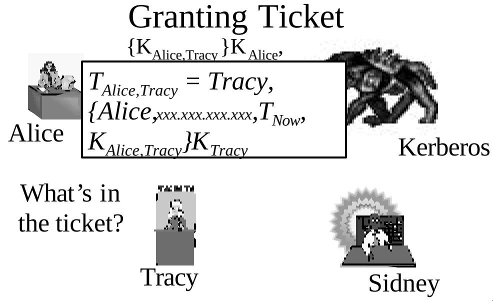
What's In a Ticket

- $T_{C,S} = s, \{c,a,v,K_{C,S}\}K_S$
- *s* is the server
- *c* is the client
- *a* is the client's network address
- *v* is a timestamp
- $K_{C,S}$ is a session key
- K_S is the server's key

Kerberos in More Detail: Step 1



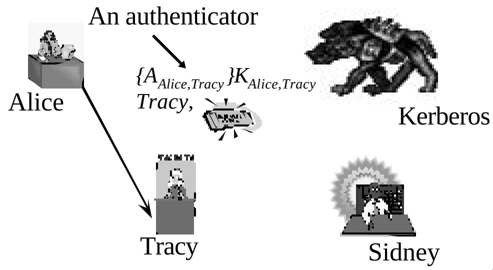
Kerberos Sends Client Ticket-Granting Ticket



So What Has the Client Got?

- K_{Alice} is derived from her password
- Which gets a session key allowing her to communicate securely with the TGS
  - $K_{Alice,Tracy}$
- And she has a ticket for the TGS
  - Not directly usable by Alice
  - But the TGS (Tracy) can use it to authenticate Alice

Client Asks TGS for a Server Ticket



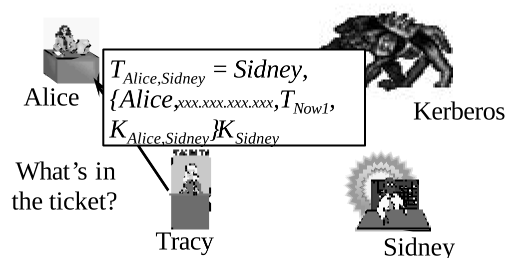
What Has the TGS Got?

- It can decrypt the ticket created by the Kerberos server
  - Obtaining $K_{Alice,Tracy}$ and other information
  - Authenticating that the transmission went through Kerberos server
- And it's got the authenticator

Why the Authenticator?

- We want to avoid involving the Kerberos server every time a client needs a ticket
- So the ticket-granting ticket will be used multiple times
- Authenticator protects against replay attacks involving the multi-use ticket-granting ticket

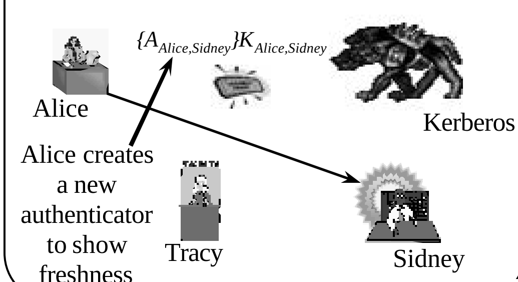
TGS Sends Ticket to Client



Now What Has the Client Got?

- She can decrypt the part of the message containing the new session key
  - So she's ready to communicate
- She can't decrypt the ticket
  - That's in a key only the server Sidney knows
  - But Sidney can use it

Client Requests Service



What Does the Server Have?

- He can decrypt the ticket from the TGS
  - Since it's in his key
- The ticket contains the session key
  - And authentication information
- He can then decrypt the authenticator
  - Which ensures a session isn't being replayed (by timestamp)

Why Is There Both a Kerberos Server and a TGS?

- The TGS handles normal interactions between clients and servers
- The Kerberos server bootstraps interactions with the TGS
  - A ticket-granting ticket can be reused with a TGS over some time
- Compromise of the TGS has limited effects

Why Is There Both a Ticket and An Authenticator?

- The ticket is reusable
  - It has a timespan
    - Typically 8 hours
- The authenticator is one-use-only
  - Supposedly
  - And its timestamp must be within the ticket's timespan

Potential Weaknesses in Kerberos

- Timestamp-based attacks
- Password-guessing attacks
- Replacement of Kerberos software
  - The server is probably well protected
  - But are the clients?
  - Not unique to Kerberos

Certificates

- An increasingly popular form of authentication
- Generally used with public key cryptography
- A signed electronic document proving you are who you claim to be

Public Key Certificates

- The most common kind of certificate
- Addresses the biggest challenge in widespread use of public keys
- Essentially, a copy of your public key signed by a trusted authority
- Presentation of the certificate alone serves as authentication of your public key

Implementation of Public Key Certificates

- Set up a universally trusted authority
- Every user presents his public key to the authority
- The authority returns a certificate
  - Containing the user's public key signed by the authority's private key

Checking a Certificate

- Every user keeps a copy of the authority's public key
- When a new user wants to talk to you, he gives you his certificate
- Decrypt the certificate using the authority's public key
- You now have an authenticated public key for the new user
- Authority need not be checked on-line

Scaling Issues of Certificates

- If there are ~600 million Internet users needing certificates, can one authority serve them all?
- Probably not
- So you need multiple authorities
- Does that mean everyone needs to store the public keys of all authorities?

Certification Hierarchies

- Arrange certification authorities hierarchically
- The single authority at the top produces certificates for the next layer down
- And so on, recursively

Using Certificates From Hierarchies

- I get a new certificate
- I don't know the signing authority
- But the certificate also contains that authority's certificate
- Perhaps I know the authority who signed this authority's certificate

Extracting the Authentication

- Using the public key of the higher level authority, extract the public key of the signing authority from the certificate
- Now I know his public key, and it's authenticated
- I can now extract the user's key and authenticate it

A Example

Alice gets a message with a certificate

Then she uses to check

Should Alice believe that he's really ?

So she uses to check

Give me a certificate saying that I'm

Alice has never heard of But she has heard of

How can prove who he is?

Certificates and Trust

- Ultimately, the point of a certificate is to determine if something is trusted
  - Do I trust the request to perform some financial transaction?
- So, Trustysign.com signed this certificate
- How much confidence should I have in the certificate?

Potential Problems in the Certification Process

- What measures did Trustysign.com use before issuing the certificate?
- Is the certificate itself still valid?
- Is Trustysign.com's signature/certificate still valid?
- Who is trustworthy enough to be at the top of the hierarchy?

Trustworthiness of Certificate Authority

- How did Trustysign.com issue the certificate?
- Did it get an in-person sworn affidavit from the certificate's owner?
- Did it phone up the owner to verify it was him?
- Did it just accept the word of the requestor that he was who he claimed to be?

What Does a Certificate Really Tell Me?

- That the certificate authority (CA) tied a public/private key pair to identification information
- Generally doesn't tell me why the CA thought the binding was proper
- I may have different standards than that CA

Showing a Problem Using the Example

Alice likes how verifies identity

What if uses 's lax policies to pretend to be ?

But is she equally happy with how verifies identity?

Does she even know how verifies identity?

Another Big Problem

- Things change
- One result of change is that what used to be safe or trusted isn't any more
- If there is trust-related information out in the network, what will happen when things change?

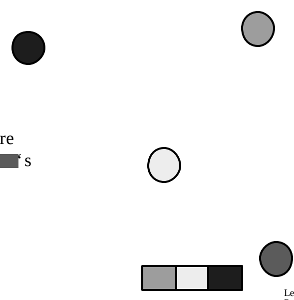
Revocation

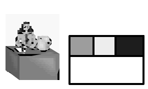
- A general problem for keys, certificates, access control lists, etc.
- How does the system revoke something related to trust?
- In a network environment
- Safely, efficiently, etc.

Revisiting Our Example

Someone discovers that has obtained a false certificate for

How does Alice make sure that she's not accepting 's false certificate?





The Web of Trust Model

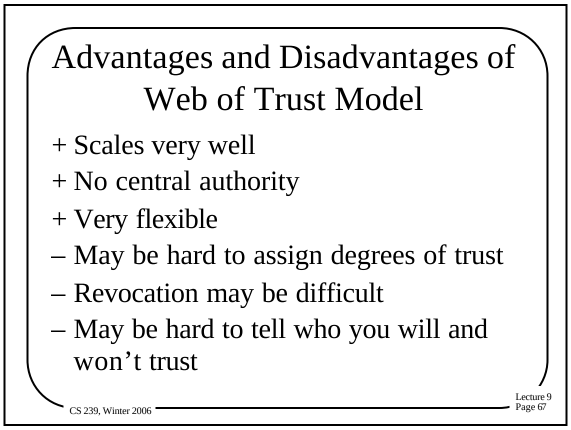
- Public keys are still passed around signed by others
- But your trust in others is based on your personal trust of them
  - Not on a formal certification hierarchy
  - "I work in the office next to Bob, so I trust Bob's certifications"

Certificates in the Web of Trust

- Any user can sign any other user's public key
- When a new user presents me his public key, he gives me one or more certificates signed by others
- If I trust any of those others, I trust the new user's public key

Limitations on the Web of Trust

- The web tends to grow
  - "I trust Alice, who trusts Bob, who trusts Carol, who trusts Dave, . . ., who trusts Lisa, who trusts Mallory"
  - Just because Lisa trusts Mallory doesn't mean I should
- Working system needs concept of degrees of trust


Advantages and Disadvantages of Web of Trust Model
+ Scales very well
+ No central authority
+ Very flexible
– May be hard to assign degrees of trust
– Revocation may be difficult
– May be hard to tell who you will and won't trust
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