CPSC 467b: Cryptography and Computer Security

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Kerberos

Kerberos

Kerberos is a widely-used authentication system and protocol developed originally by M.I.T.'s Project Athena in the 1980's.

The protocol was named after the character Kerberos (or Cerberus) from Greek mythology which was a monstrous three-headed guard dog of Hades.

http://collectionsonline.lacma.org/mwebcgi/mweb.exe?request=record;id=12845;type=101

Simple authentication protocol

Alice and Bob want to communicate privately.

If they already share a private key K, they can just send encrypted messages to each other.

Problems with this approach:

1. Every time Alice uses K, she exposes it to possible cryptanalysis, so she really only wants to use it to establish a *session key* K_{ab} to encrypt her message to Bob.
2. Alice needs a different key for each different user she might wish to communicate with. In an N-party system, this could require $O(N^2)$ keys and becomes unwieldy.

Kerberos overview

Kerberos overcomes these problems by using a trusted server called the *Key Distribution Center (KDC)*.

Every user shares a key with the KDC.

When Alice wishes to talk to Bob, she asks the KDC to generate a session key K_{ab} for them to use.

The KDC uses Alice and Bob's private keys K_a and K_b for authentication and for the secure distribution of the session key K_{ab} to Alice and Bob.

Problems to overcome

The protocol must overcome several problems to be useful in practice:

- Network security is not assumed, so uses must never send their private keys over the network.
- Once Alice obtains K_{ab}, she needs a way of verifying that the other party holding K_{ab} is really Bob and not someone else pretending to be Bob.
- Users do not want to be constantly asked to provide their passwords, so a *single sign-on (SSO)* system is desirable.
- In a large system, the KDC could become a bottleneck, so it needs to be scalable.

Parties to the protocol

Four parties are involved in the basic protocol:

- The *authentication server (AS)*;
- The *ticket granting server (TGS)*;
- The *client, Alice in our examples*;
- The *service server (SS), Bob in our examples*.

The KDC contains the database of all keys and generally runs both the AS and the TGS.

Basic protocol

At a high level, the basic protocol consists of three phases:

1. Alice authenticates herself to the AS and receives a *ticket granting ticket (TGT)* in return.
2. Alice presents a TGT to the TGS to obtain an *Alice-to-Bob ticket*.
3. Alice presents the Alice-to-Bob ticket to Bob in order to obtain service.

Alice only uses her private key in step 1. The TGT obtained in step 1 contains a *client/TGS session key* that is used for securely communicating with the TGS in step 2.

Phase 1: Obtaining a TGT

Alice authenticates herself to AS and obtains a TGT.

- Alice sends a cleartext message with her ID “a” to the AS.
- The AS obtains Alice’s secret key K_a from the database and sends back two messages:
  1. Message A: A Client/TGS session key $K_{a,\mathrm{TGS}}$, encrypted with K_a.
  2. Message B: A TGT (Alice’s ID, her IP address, expiration time, $K_{a,\mathrm{TGS}}$), encrypted with K_{TGS}.
- Alice decrypts message A to obtain $K_{a,\mathrm{TGS}}$. She is unable to decrypt message B.

Phase 2: Obtaining an A-to-B ticket

Alice uses her TGT to obtain an Alice-to-Bob ticket (A-to-B).

- Alice sends two messages to the TGS:
  1. Message C: (Message B, Bob's ID).
  2. Message D: (Alice's ID, timestamp), encrypted with $K_{a,\text{TGS}}$.
- The TGS retrieves message B from message C and decrypts it to get $K_{a,\text{TGS}}$, which it then uses to decrypt message D. It checks Alice's ID and IP address, generates a session key K_{ab} and then sends two messages to Alice:
  1. Message E: A-to-B ticket = (Alice's ID, her IP address, expiration time, $K_{a,b}$), encrypted using K_b.
  2. Message F: $K_{a,b}$, encrypted using $K_{a,\text{TGS}}$.

Phase 3: Authenticating herself to Bob

Alice uses her A-to-B ticket to authorize herself to Bob.

- Alice sends two messages to Bob:
    1. Her A-to-B ticket, which she received from TGS as Message E.
    2. Message G: An authenticator = (Alice ID, timestamp), encrypted with $K_{a,b}$.
- Bob decrypts the ticket to retrieve $K_{a,b}$, which he uses it to decrypt the authenticator. He sends the following message to Alice:
    1. Message H: (1 + timestamp from the authenticator), encrypted with $K_{a,b}$.
- Alice decrypts and checks message H for correctness.

Use in practice

Tickets have a relatively long lifetime and can be used many times.

Authenticators have a relatively short lifetime and can be used only once.

The latest protocol has additional security enhancements beyond those described here.

Advantages of Kerberos

- Passwords arent exposed to eavesdropping.
- Password is only typed to the local workstation.
  - It never travels over the network.
  - It is never transmitted to a remote server.
- Password guessing is more difficult.
- Single sign-on.
  - More convenient: only one password, entered once.
  - Users may be less likely to store passwords.
- Stolen tickets hard to reuse.
  - Need authenticator as well, which cant be reused.
- Much easier to effectively secure a small set of limited access machines (the KDC).
- Easier to recover from host compromises.
- Centralized user account administration.

Drawbacks and Limitations

- Kerberos server can impersonate anyone.
- KDC is a single point of failure.
  - Can have replicated KDCs.
- KDC could be a performance bottleneck.
  - Everyone needs to communicate with it frequently.
  - Not a practical concern these days.
  - Having multiple KDCs alleviates the problem.
- If local workstation is compromised, users password could be stolen.
  - Only use a desktop machine or laptop that you trust.
  - Use hardware token pre-authentication.
- Kerberos vulnerable to password guessing attacks.
  - Choose good passwords!
  - Use hardware pre-authentication.
    - Hardware tokens, Smart cards etc.

Secure Shell (SSH)

Secure Shell (SSH)

SSH is a family of protocols that provide a secure encrypted channel connecting two networked computers over an insecure network.

It was initially designed to allow secure login between a user and a remote computer. This replaced the older `telnet`, `rlogin`, and `rsh` programs that provided unencrypted versions of this service and sent unencrypted passwords over the network.

The first version was designed by Tatu Ylönen at Helsinki University of Technology, Finland, and released as freeware in July 1995.

Open source and version forking

By December 1995, Ylönen created a startup company to market and develop SSH. The original version remained free, but many enhancements were only available in the commercial version.

Over the next five years, the licensing agreement became more and more restrictive as they worked to remove open source code (such as libgmp) from their code base.

Several vulnerabilities in SSH-1.5 were discovered, giving further motivation to create an open source version of SSH that could be more easily vetted for bugs and distributed more widely.

Starting from Ylönen's SSH-1.2.12, the last version released under an open source license, Björn Grönvall developed OSSH. OpenBSD developers then forked Grönvall's code and did further development to create the widely used OpenSSH.

SSH-2

By 2006, an improved but incompatible version 2 of the SSH protocol was adopted as a standard by the Internet Engineering Task Force (IETF).

Development of OpenSSH continues to this day, allowing more and more applications derive the benefits of secure encrypted communications.

SSH protocol outline

SSH is based on public key cryptography. Each machine has a public and private *host key*. Each user also has a public and private *user key*.

When logging onto a remote machine, the client first authenticates the remote host key using the public key for the host with that domain name or IP address found in the local `known_hosts` file.

Host key verification

If the host is not in the file or cannot authenticate the public key found there, one gets a prompt

```
The authenticity of host 'vm1.cs.yale.edu (128.36.229.150)' can't be established.
RSA key fingerprint is c9:a5:be:55:af:ab:05:77:b4:30:62:ed:bd:be:50:43.
Are you sure you want to continue connecting (yes/no)?
```

If you say yes, the public key of that host gets entered into the `known_hosts` file and used the next time.

User authentication

SSH supports several authentication methods. I'll describe the `publickey` method.

Here, the host checks that the user's public key is in its `authorized_users` file. If it is, it verifies that the user has the matching private key and accepts the authentication if it does.

Actual protocol

The actual protocol is much more complicated than this.

It include negotiations for which cipher to use, how to generate the shared session, what an encrypted packet looks like, and so forth.

Transport Layer Security (TLS)

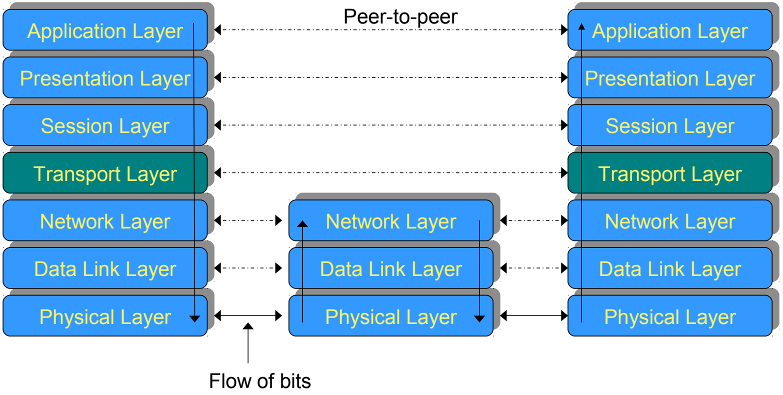
TLS protocol

Transport Layer Security (TLS) is a protocol to secure and encrypt network traffic at the transport layer.

Like SSH, it provides authentication and encryption.

It is used to implement secure web traffic (`https:`) but applies much more generally.

ISO/OSI Model SSL: Security at Transport Layer



History

The TLS protocol has gone through several versions. It was originally called *Secure Socket Layer (SSL)*.

TLS 1.0 was first defined in 1999. It did not interoperate with the existing SSL 3.0 and so was renamed.

Key management

TLS uses X.509 certificates for its key management as described in lecture 16.

They allow the client to authenticate the server as follows:

1. The client obtains the server's certificate, generally from the server itself.
2. The client checks the validity of the certificate by verifying that it is properly signed by a trusted certificate authority.
3. The client then runs a simple authentication protocol whereby the server shows that it has the private key corresponding to its certificate.
4. Finally, client and server establish a shared symmetric key and use it to encrypt traffic between themselves.

The actual protocol

The actual protocol has all of the complications of the other practical protocols we've mentioned.

- It begins with a handshaking phase where client and server agree on the protocol level, cipher suite, and other parameters.
- Generally the server is authenticated by the client.
- The protocol allows for the server to require client authentication. However, this is not usually done for two reasons:
  1. Most clients lack certificates.
  2. Most servers use other means such as passwords to authenticate clients. This occurs after the encrypted connection has been established, so the passwords are not sent in the clear.

Preventing man-in-the-middle attacks

TLS is secure against man-in-the-middle attacks, even with only one-way authentication.

This is possible because the certificate give the client a reliable means of obtaining its public key.

At the end of the handshaking protocol, after the session key has been established, the client sends the server the hash of the complete transcript between client and server as seen by the client, secured with the server's public key.

The server checks that hash value against the hash of its view of the same handshake. If they don't agree, it indicates the presence of a man-in-the-middle or other network error and the protocol does not continue.

Digital Rights Management and Trusted Computing Platform

Control of information

Another attempted use of cryptography has been to control the use of information.

Digital Rights Management (DRM) is the term for a class of encryption schemes to disallow certain kinds of use of data, for example, copying and modifying.

Trusted Computing Platform (TCP) is a hardware architecture that requires authorization tokens to perform certain operations. These tokens are cryptographically produced using keys that are securely stored inside of a special crypto module.

A different paradigm

In most uses of cryptography studied so far, the owner of the secret keys also possesses and protects them.

With DRM and TCP, the party controlling the keys is not the same as the owner of the machine that uses them.

This means that the keys must be hidden from the owner of the device on which they are used.

While it is easy to prevent casual users from looking inside their box, protecting embedded secrets against sophisticated attacks has proved to be very difficult, and many DRM schemes have been broken soon after being introduced.