Security building blocks: protocols

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Lecture topics

- Basic security protocols
- Security protocols
- Unsecurity in protocols

For what are protocols needed

- Exchanging session keys
- Authenticating

Where to locate encryption

- Link layer
  - all communication protected on protected links
  - intermediate nodes must be trusted
  - popular on wireless links
  - problems on high-speed links
  - GSM, WEP, PPP Encryption[5]
- Network layer
  - end-to-end ecryption (if not a tunnel mode)
  - all communication between hosts protected
  - OS modifications needed
  - applications may work as is
  - IPSec
- Transport layer
  - underlying protocol provides retransmissions
  - applications may need to be adapted
  - faster to deploy
  - TLS
- Application layer
  - application-specific optimisation
  - must be implemented for each protocol
  - possibly protects data on when not in transit
  - faster to deploy
  - PGP

Generating keys

- (Session) keys must not be predictable
  - Netscape 1.1 used only the time of day, the process ID, and the parent process ID to generate SSL keys
- True randomess difficult in computers
- Pseudo-random numbers $x_{n+1} = (1103515245x_n + 12345) \bmod 2^{31}$, $x_1 = seed$[1]
- Real-world sources
  - quantum physics `http://www.randomnumbers.info/`
  - time measurements from events
    - keyboard codes and intervals
    - mouse movements
    - interrupts (disk, network)
- Pool of randomnees (in Linux)
  - source for cryptographic hash function[2]

  `/dev/random` does not return more than estimated amount of randomness

  `/dev/urandom` returns as much as wanted
  ⇒ maybe vulnerable to hash analysis

Key exchange with symmetric ciphers

- Use of trusted third party $\mathcal{C}$
  1. $\mathcal{A} \rightarrow \mathcal{C} : \{\text{request for session key to Bob}\}\mathcal{K}_{\mathcal{A}}$
  2. $\mathcal{C} \rightarrow \mathcal{A} : \{\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{A}} || \{\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{B}}$
  3. $\mathcal{A} \rightarrow \mathcal{B} : \{\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{B}}$
- Problems
  - $\mathcal{B}$ does not know with whom to talk
  - replay attacks possible

Needham-Schroeder [6]

1. $\mathcal{A} \rightarrow \mathcal{C} : \{\mathcal{A}||\mathcal{B}||rand_1\}$
2. $\mathcal{C} \rightarrow \mathcal{A} : \{\mathcal{A}||\mathcal{B}||rand_1||\mathcal{K}_{\mathcal{A},\mathcal{B}}||\{\mathcal{A}||\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{B}}\}\mathcal{K}_{\mathcal{A}}$
3. $\mathcal{A} \rightarrow \mathcal{B} : \{\mathcal{A}||\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{B}}$
4. $\mathcal{B} \rightarrow \mathcal{A} : \{rand_2\}\mathcal{K}_{\mathcal{A},\mathcal{B}}$
5. $\mathcal{A} \rightarrow \mathcal{B} : \{rand_2 - 1\}\mathcal{K}_{\mathcal{A},\mathcal{B}}$

- *rand*s used to defeat replay
  - must not be repeated
  - nonce[3]
- If a session key is compromised, it is possible to masquerade using old exchange
  - use timestamps $\mathcal{T}$ [2]
    ⇒ need for accurate and *secure* clocks
  - use message numbers [7]
    ⇒ keep track with numbers with each party

[1] Not a very good generator: period of 2^{31} and lowest bits are not very random.
[2] strong mixing function
[3] Designating a lexical item formed for use on a specific occasion.

Kerberos 5 [4]

- Uses Needham-Schroeder with timestamps
- Provides

  secure passwords are not stored on disk or transmitted over network
  single-sign-on as user logs in only once for all resources
  trusted third-party central authentication server
  mutual authentication as services are authenticated also

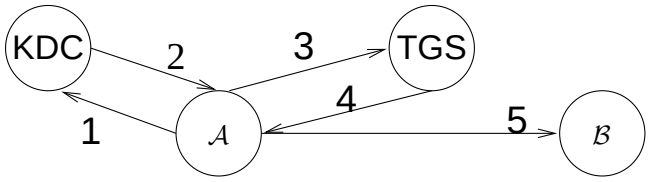
- Assumptions
  - denial of service attacks are not handled by kerberos
  - principals keep their keys secret
  - passwords are of sufficient strength
  - loosely syncronised clocks
  - principal indentifiers are not recyled

Messages in Kerberos 5

Components: KDC = Key Distribution Center, TGS = Ticket Granting Service

- Uses tickets $T_{\mathcal{A},\mathcal{B}} = \mathcal{B}||\{\mathcal{A}||\text{Address}_{\mathcal{A}}||\mathcal{T}_{\text{valid}}||\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{B}}$

  1. $\mathcal{A} \rightarrow \mathsf{KDC} : \{\mathcal{A}||\mathsf{TGS}\}$
  2. $\mathsf{KDC} \rightarrow \mathcal{A} : \{\mathcal{K}_{\mathcal{A},\mathsf{TGS}}\}\mathcal{K}_{\mathcal{A}}||T_{\mathcal{A},\mathsf{TGS}}$
  3. $\mathcal{A} \rightarrow \mathsf{TGS} : \{\mathcal{B}||Auth_{\mathcal{A},\mathsf{TGS}}||T_{\mathcal{A},\mathsf{TGS}}\}$
  4. $\mathsf{TGS} \rightarrow \mathcal{A} : \mathcal{A}||\{\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{A},\mathsf{TGS}}||T_{\mathcal{A},\mathcal{B}}$
  5. $\mathcal{A} \rightarrow \mathcal{B} : \{Auth_{\mathcal{A},\mathcal{B}}||T_{\mathcal{A},\mathcal{B}}\}$[4]
  6. $\mathcal{B} \rightarrow \mathcal{A} : \{\mathcal{T}+1\}\mathcal{K}_{\mathcal{A},\mathcal{B}}$
     The last step is optional.



Kerberos weaknees

- Need for synchronised clocks
  - authenticator valid for 5 minutes
- Known plaintext attacks
  - fixed fields in messages
  - no “salt” used
- Consequences of compromises
  - root on KDC
    - *all credentials compromised*
  - Kerberos administrator credentials
    - all credentials compromised

[4] *Auth* includes recent timestamp encrypted with session key.

- root on server machine
  - all services on machine. If there is some distributed service, such as Andrew File System (AFS) that shares service principals across multiple machines, all of those are compromised. Note that no client credentials are exposed expect for brute-force attack as if captured from the network.
  - can impersonate to server
  - all traffic between clients and the server can be decrypted over the period that same key has been used
- root on client machine
  - cached tickets on that machine
  - passwords entered into machine when compromised. Passwords entered earlier are not vulnerable as they are not stored after $\mathcal{K}_{\mathcal{A},\mathsf{TGS}}$ is received.
- user credentials
  - tickets can be used for their lifetime
  - if password is known, then account is compromised

Public key exchange

- Simple in principle: $\mathcal{A} \rightarrow \mathcal{B} : \{\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{B}p}$
- However, $\mathcal{A}$ not authenticated
  $\Rightarrow \mathcal{A} \rightarrow \mathcal{B} : \{\{\mathcal{K}_{\mathcal{A},\mathcal{B}}\}\mathcal{K}_{\mathcal{A}s}\}\mathcal{K}_{\mathcal{B}p}$
- Where to get $\mathcal{K}_{\mathcal{A}p}$, $\mathcal{K}_{\mathcal{B}p}$?
  - a directory would be mother of all targets
    $\Rightarrow$ something not depending integrity of large, public access database
- Certificate: a token that binds an *identity* to a key
  - tree stucture: *root* is known out-of-band
  - free-form chain: different trust is placed

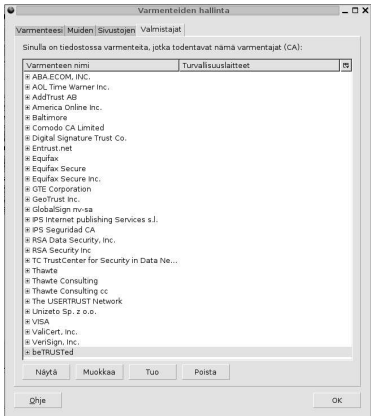
X.509 — the Directory authentication FrameWork

- ITU X.509v3 issued 1993
- Certificate has following components
  1. version (=3)
  2. serial number that is unique for issuer
  3. signature algorithm
  4. issuer's distinguished name
  5. validity interval
  6. subject's distinguished name
  7. public key information
  8. issuer's unique indentifier
  9. subject's unique indentifier
  10. extensions
  11. signature (calculated over other components)

Ideal certificate/PKI world

- A certificate for each
  - web site
  - email sender
  - citizen
  - corporation, society, community
- Each transaction would become verifiable
- All certificates could be verified using certificate tree

Who do you trust



Obstacles in Certificates

- Bootstrap information needed
  - which CAs to select?
  - one with USD 1000 / year / server or USD 25 / year: the first with 100 % browser compatibility, the other with 95 – 99 % compatibility.
- Transfering *trust*
- Certificate revocation list (CRL)
  - similar to credit card blacklists
  - often not used
- Naming identities
  - how about namesakes
  - certificate identities may not be unique across registries
  - implement or rely on registry, such as domain name system but this creates yet another trust issues.
    ⇒ complicates implementation
- Certificate information does not give enough information to build trust
- Keeping secret key really secret

OpenPGP [1]

- Based on original PGP developed 1991 by Philip Zimmerman
- Web of trust
  - different trust levels

    undefined nothing is known
    marginal maybe valid
    complete key is valid
  - keys self-signed
  - multiple signatures, with different levels of trust on signatures

    unknown nothing is known
    none improperly signing one
    marginal understands implications and validates keys
    full as good as you
- Multiple signatures

Transport Layer Security [3]

- Provides data privacy and confidentiality
  - protocol-independet
  - supports large selection of crytographic algorithms
- TLS Record protocol
  - symmetric cryptology for privacy
  - reliable connection
  - runs top on reliable byte stream (TCP)
  - encapsulates other protocols
- TLS Handshake protocol
  - peer identity can be authenticated: optional, but in normal case at least other of peers is authenticated using asymmetric cryptology.
  - shared secret negotiated secure also for man-in-middle attack
  - reliable negotiation

TLS handshake

1. $\mathcal{C} \rightarrow \mathcal{S}$: ServerHello,
2. $\mathcal{S} \rightarrow \mathcal{C}$: *Sertificate, ServerKeyExchange, CertifacateRequest*ServerHelloDone
3. $\mathcal{C} \rightarrow \mathcal{S}$: *Sertificate*, ClientKeyExchange*CertificateVerity*, ChangeCiperSpec,Finished
4. $\mathcal{S} \rightarrow \mathcal{C}$: ChangeCiperSpec,Finished
5. $\mathcal{C} \leftrightarrow \mathcal{S}$: Application Data

Internet Key Exchange

- Used for IPSec key exchange
- Security assosiation established
  - encryption algorithm
  - hash algorithm
  - authentication method
  - Diffie-Hellman modulus
- Main and aggressive mode
- Maintains security assosiation descriptions

Key storage

- Computer memory
  - superuser can read
  - other processes by the same user
  - may end to hard disk as a result from paging
- Special hardware on computer
  - may provide key functions
  - no access to key
- External token
  - can be removed from system when not in use
  - becomes protected asset
- Smart card
  - can keep secret keys internal

Summary

- Use encryption and integrity checks on right level
- Avoid protocols needing hot spots
- Securing one location is easier than securing multiple locations, however

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[7] Dave Otway and Owen Rees. Efficient and timely mutual authentication. *SIGOPS Oper. Syst. Rev.*, 21(1):8–10, 1987.