Authentication

- Motivation
- Authentication protocols in different scenarios
- X.509, Kerberos

Authentication

- Alice needs to show her identity to Bob; she needs to get a service, or to access information, or a resource etc.
- Bob needs to be sure of Alice's identity:
  - Who is Alice?
- Trudy tries to impersonate Alice:
  - Once
  - Many times

Authentication

- The process of reliably verifying the identity of someone (or something).
- In human interaction:
  - People who know you can recognize you based on your appearance or voice
  - A guard might authenticate you by comparing you with the picture on your badge
  - A mail order company might accept as authentication the fact that you know the expiration date on your credit card
- Two interesting cases
  - a computer is authenticating another computer
  - a person is using a public workstation that can perform sophisticated operations, but it will not store secrets for every possible user
    - the user's secret must be remembered by the user

Closed world assumption

- Presumption that what is not currently known to be true, is false
  - the opposite of the closed world assumption is the open world assumption, stating that lack of knowledge does not imply falsity
- *Negation as failure* is related to closed world assumption, as it believes false every predicate that cannot be proved to be true

Closed environment

- Authentication in a closed environment (e.g. company, home)
- We use a third party Carole (trusted server) distributing required information for authentication (before authentication or using secret communication)
- Trudy is a legal user and might use the connection Alice-Bob

Human vs computer authentication

- What's the difference between authenticating a human and authenticating a computer?
- computer can store a high-quality secret, such as a long random-looking number, and it can do cryptographic operations
- a workstation can do cryptographic operations on behalf of the user, but the system has to be designed so that all the person has to remember is a password
- password can be used to acquire a cryptographic key in various ways:
  - directly, as in doing a hash of the password
  - using the password to decrypt a higher-quality key, such as an RSA private key, that is stored in some place like a directory service

Authentication of people

Use

- What you know (passwords)
- What you have (smart card)
- Who you are (biometric tools)
- Where you are (network address - weak, because of spoofing)

Password

- Humans:
  - Short keys, that possibly allow to obtain long keys
  - Sometimes easy to guess
- Computers:
  - Long keys
  - Hidden (not stored in clear): either stored encrypted or indirectly
  - One-time password
- a well know threat is the login Trojan horse: the attacker prompts a fake login window that induces the innocent user to prompt the password that is collected by the attacker


NetBSD/vax (landtest02) (console)
login:
Printer: None
TH Darmstadt
VT320

Biometric

- There are many devices that are used to authenticate:
- Retina examination, fingerprint reader, voice, or based on other characteristics (ex. hand written signatures, keystroke timing: timing in using the keyboard or the mouse etc.)
- Accuracy:
  - Error: false positive and false negative
  - They are used in specific scenarios (sometimes to enforce other methods)

Biometric

- Fingerprinting:
  - Fake fingerprint, dead people
  - Not stable over time: children, people doing manual work (possible damage)
- Voice
  - Use of tape;
  - voices are affected: flu and colds; noise in the background, telephone etc

Biometric

- Keystroke timing:
  - Each person has different speed in typing
  - Typing faster than personal limit is impossible
- Handwritten signature:
  - Poor quality
  - Electronic tablet, for signature + timing

Authentication scenarios

In the following we will consider authentication using knowledge of a key (public key or secret key, possibly stored in a smart card)

1. Users (Alice and Bob) share a secret key
2. Users share a key with Carole, trusted authority (authentication server)
3. Users have a public key

Techniques

Users are authenticated using a key

Techniques:

- timestamp
- nonce (or challenge): random number chosen by the person that authenticates to verify the other knows the key
- sequence number in protocols

Cryptography vs. authentication

- Trudy attacks the protocols using non authentic messages (possibly messages that have been exchanged between Alice and Bob in previous application of the protocol)
- Need to guarantee authentication and integrity
- Encryption DOES NOT guarantee authenticity of the message

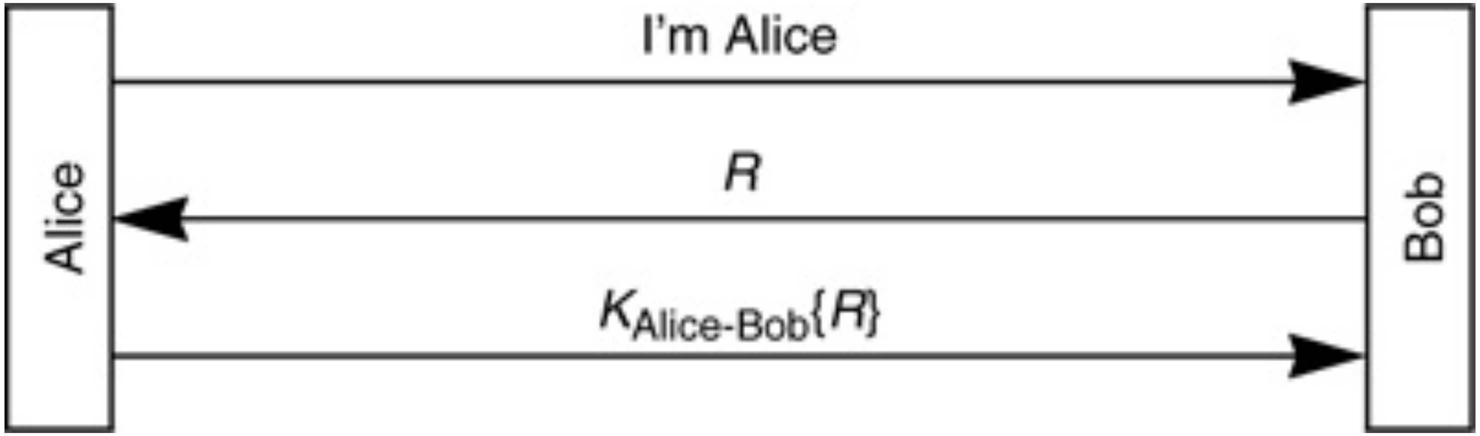
Authentication by symmetric key

Alice and Bob share a secret key $K_{Alice\text{-}Bob}$

K{M} denotes M encrypted with secret key K

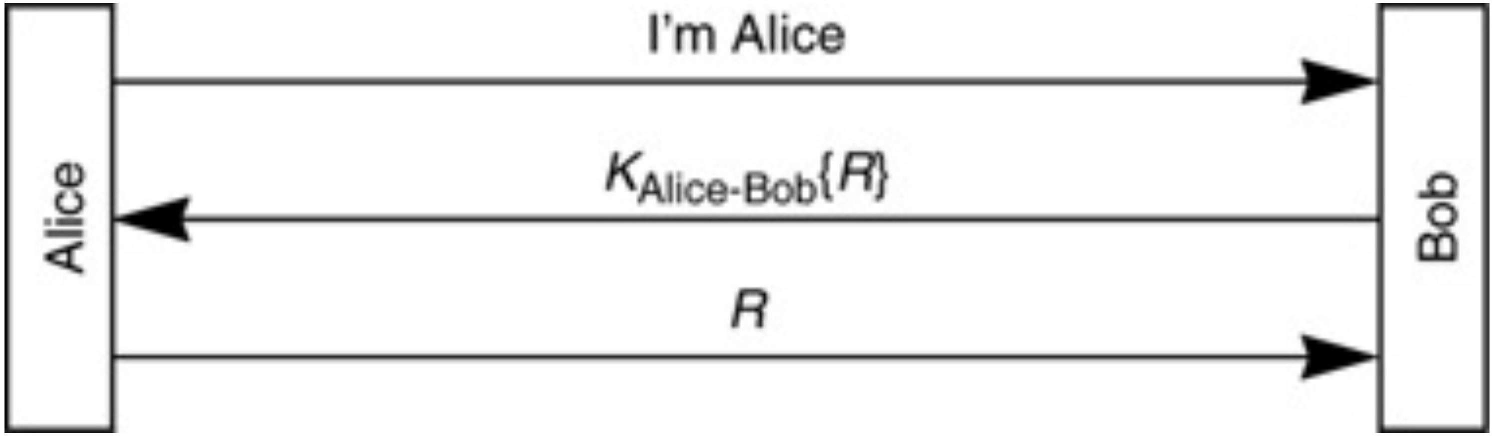
- One way authentication using nonce (challenge)
- One way authentication using timestamps
- Two ways (mutual) authentication using nonce

challenge/response based on shared secret



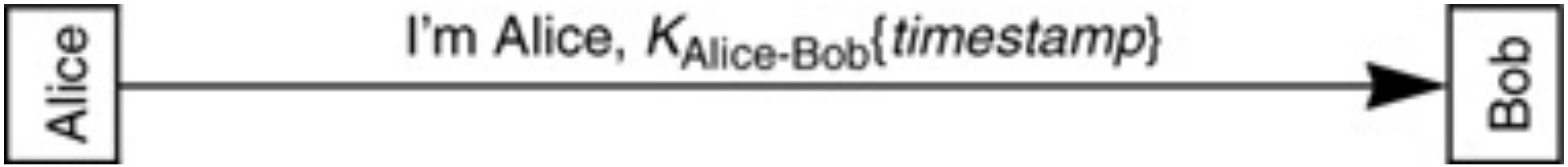
- authentication is not mutual. Bob authenticates Alice, but Alice does not authenticate Bob
- an eavesdropper could mount an off-line password-guessing attack (assuming $K_{Alice\text{-}Bob}$ is derived from a password), knowing R and $K_{Alice\text{-}Bob}\{R\}$
- R is a nonce

variant



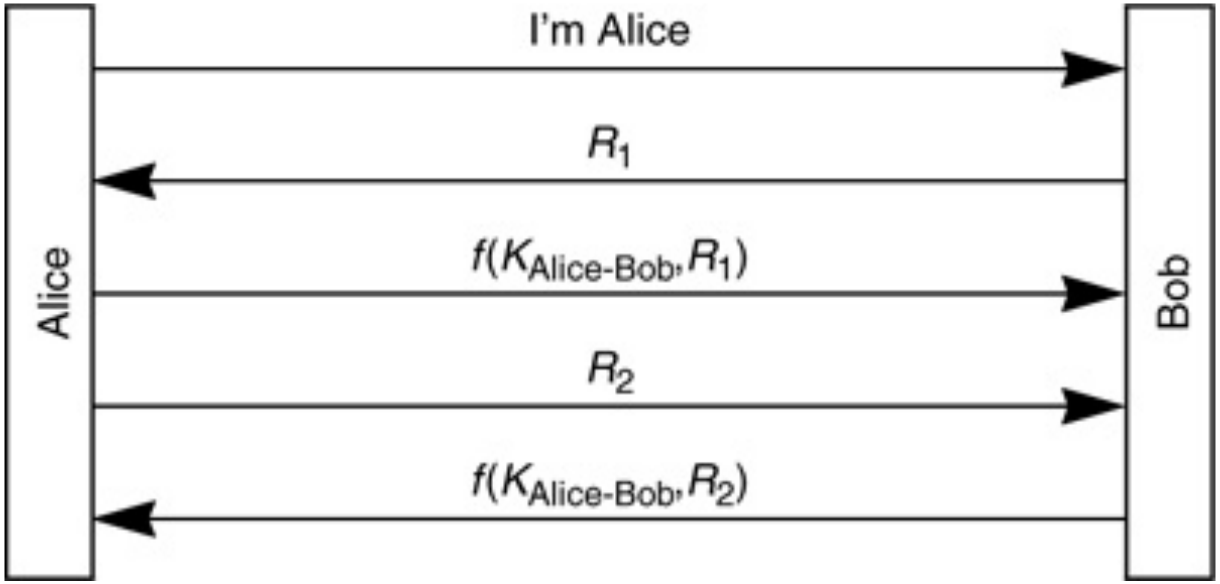
- requires reversible cryptography
- still possible the dictionary attack by eavesdropper
- if R has limited lifetime (e.g., random number + timestamp) Alice authenticates Bob because only someone knowing $K_{Alice\text{-}Bob}$ could generate $K_{Alice\text{-}Bob}\{R\}$
  - limited lifetime required to foil replaying of an old $K_{Alice\text{-}Bob}\{R\}$

timestamp based



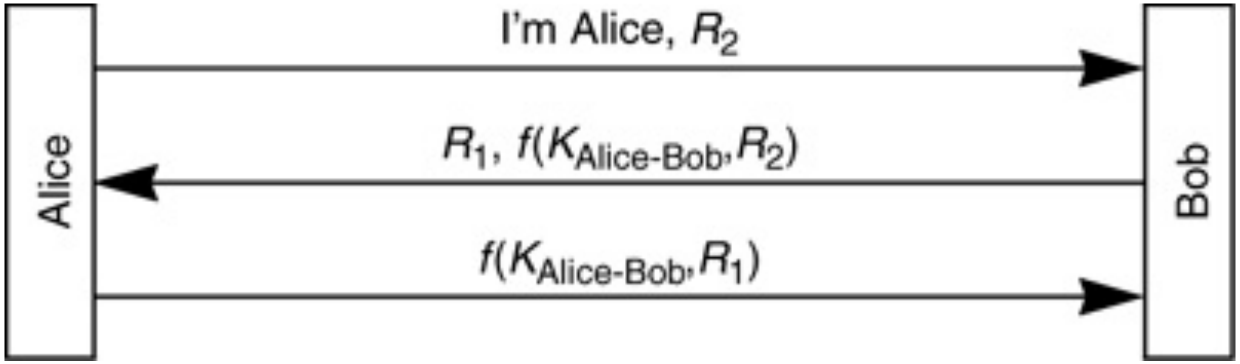
- Bob and Alice have reasonably synchronized clocks (can be a weakness)
- Alice encrypts the current time, Bob decrypts the result and makes sure the result is acceptable (i.e., within an acceptable clock skew)
- efficient, no intermediate states
- if Bob remembers timestamps until they expire, then no replaying attacks
- if multiple servers with same secret *K*, then Alice can send *K*{Bob|*timestamp*}

mutual authentication



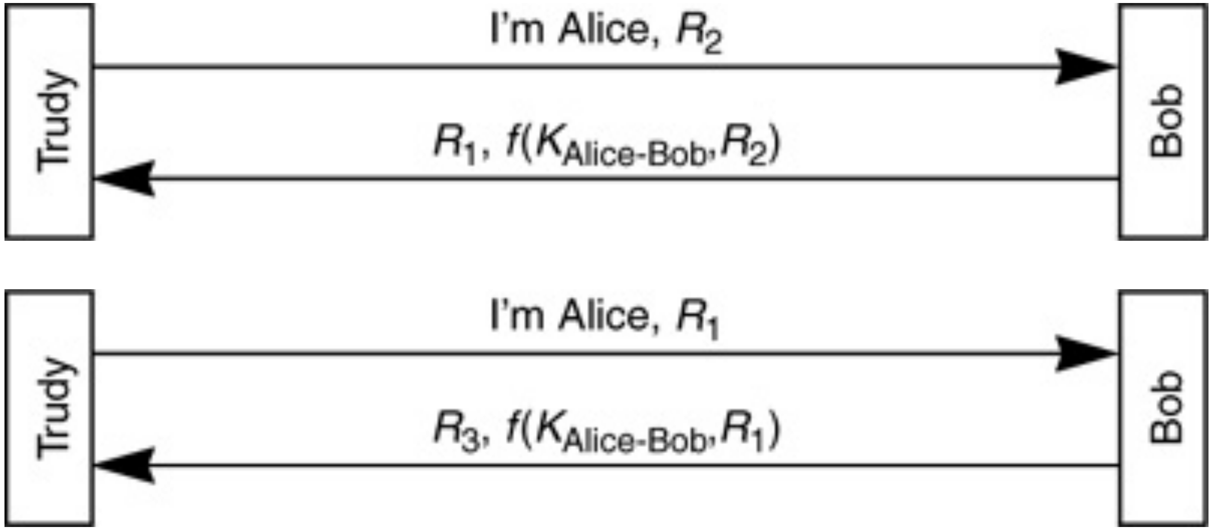
- many messages!
- perhaps a few ones can be saved...

optimized mutual authentication



- save messages but weak to reflection attack

reflection attack

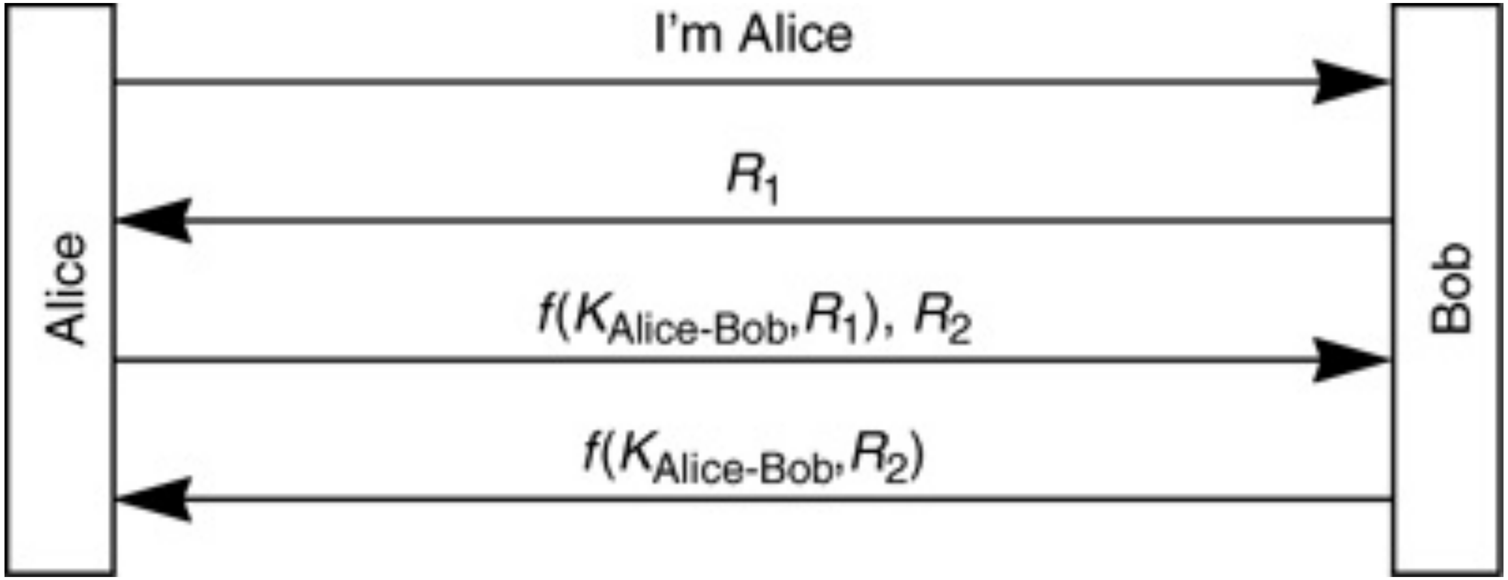


- Trudy wants to impersonate Alice to Bob
- two sessions, the 2nd will be incomplete but will allow Trudy to complete the 1st one

how to prevent reflection attack?

- use different keys
  - $K_{\text{Alice-Bob}}$ and $-K_{\text{Alice-Bob}}$, or $K_{\text{Alice-Bob}} + 1$
- different challenges, i.e. challenge from initiator different from challenge from responder
  - e.g., even number at initiator's side, odd number at responder's side

less optimized mutual authentication



- Trudy can mount an off-line password-guessing attack by impersonating Bob's address and tricking Alice into attempting a connection to her

Trusted party

It is not possible that all users share a secret key (quadratic number of keys, each user must have a different key for everyone)

Scenario: users share a key - password - with trusted authority C - C authentication server (aka Key Distribution Center (KDC))

- A and B share a secret key with C (K_{AC} e K_{BC})
- A and B might not be human user but also entity of the system (e.g., printer, databases etc.)
- Goals: authenticate A (or A and B);
  - optional: decide on a session key to be used between A and B for short time

Authentication server

Goal: Alice and Bob must authenticate and choose a secret session key K - used for short time (session)

At the end of the authentication protocol:

1. only A and B know K (besides C - trusted server)
2. Each should be sure of fact 1 above
3. K is a new key (randomly chosen, not used before)

Authentication server - attacker's strength

Trudy (attacker) can

- be a legitimate user of the system (share a key with C)
- sniff and spoof messages
- concurrently run more than one session with A, B and C
  - different execution of the protocol can be done interleaved
  - T is able to convince A and/or B to start a new session with T
- Might know old session keys

Authentication server - attacker's limits

Trudy

- is NOT able to guess random numbers chosen by A or B
- does not know keys K_{AC} and K_{BC} (in general does not know secret keys of other users)
- is not able to decode in a short time messages encrypted with unknown keys

Authentication with trusted server

A and B share a key with C (K_{AC} and K_{BC}, respectively)

1. A sends to C: A, B
2. C chooses K - session key - and sends to A:
   K_{AC}(K) and K_{BC}(K)
3. A decodes and computes K and sends to B:
   C, A, K_{BC}(K)
4. B decodes K_{BC}(K) finds K and sends to A:
   K(Hello A, this is B)

Attack - 1

Assume T can sniff, spoof and make MITM attack (T is in the middle of both A to C and A to B communication)

1. A sends to T (instead of A sends to C) : A,B
2. immediately T sends to C: A,T
3. C chooses K and sends to A: $K_{AC}(K)$ and $K_{TC}(K)$
4. A sends to B: C, A, $K_{TC}(K)$ - T intercepts
5. T sends to A K(Hello A, this is B)

Possible modification of step 1 (previous slide):

A sends to C <A, $K_{AC}(B)$> (in this way C knows that A wants to talk to B)

Attack - 2

Modified protocol

1. A sends to C: A, $K_{AC}(B)$
2. C chooses K, and sends to A: $K_{AC}(K)$ and $K_{BC}(K)$
3. A decodes K and sends to B: C, A, $K_{BC}(K)$
4. B decodes K and sends to A : K(Hello A, this is B)

Note: T does not know that A wants to talk to B

Attack - 3

Consider modified protocol

1. A sends to C : A, K_{AC}(B)
   T (as A) gets A's message and sends to C: A, K_{AC}(T) (REPLAYS part of some previously exchanged message)
   Note: T does not know whom A wants to talk to
2. C chooses K, and sends to A : K_{AC}(K) and K_{TC}(K)
3. A decode K and sends to B : C, A, K_{TC}(K)
4. T gets the message and finds that A wants to talk to B; T now acts in place of B and sends to A K(Hello A, this is B)

Note: T knows the identity the person A wants to talk to only at the end of the protocol

Protocol Needham-Schroeder

basis for the Kerberos protocol and aims to establish a session key between two parties on a network, typically to protect further communication

N, nonce: random number

N.-S. protocol based on challenge-response :

1. A chooses N (nonce) and sends to C: A, B, N
2. C chooses K and sends to A: K_{AC}(N, K, B, K_{BC}(K, A))
3. A decodes, checks N and B, and sends to B: K_{BC}(K, A)
4. B decodes, chooses nonce N' and sends to A:
   K(this is B, N')
5. A sends to B K(this is A, N' - 1)
   now B has checked A

Note: B does not directly communicate with C

Attacking N.-S. Protocol

1. A chooses N (nonce) and sends to C: A, B, N
2. C chooses K and sends to A: K_{AC}(N, K, B, K_{BC}(K, A))
   now T acts in place of A
3. A decodes, checks N and B and sends to B: K_{BC}(K, A)
   T (as A) replays to B: K_{BC}(K', A), where K' is an older session key
4. B decodes, chooses nonce N' and sends to T (not to A) K'(this is B, N')
5. T sends to B: K'(this is A, N' - 1)

Note:

1. T uses old session key and acts in place of A
2. B is not sure that C is active: there is no direct exchange between B and C

Authentication attack (Denning and Sacco, '81)

- two sessions
- assume that Trudy has recorded session 1 and that K is compromised
- after session 2, B is convinced that he shares the secret key K only with A

session 1, session 2

1. A -> C: A, B, N
2. C -> A: K_{AC}(N, B, K, K_{BC}(K, A))
3. A -> I(B): K_{BC}(K, A)

assume that K is compromised

4. I(A) -> B: K_{BC}(K, A) *replay*
5. B -> I(A): K(N')
6. I(A) -> B: K(N' - 1)

B is now convinced that he shares secret key K only with A

Challenge-response symmetric key

How to guarantee data integrity

- timestamps (a message is valid only in a small time window)
- sequence number (A and B remember sequence number of exchanged messages to avoid replay attacks in which the attacker sends old messages)
- nonce should be used carefully

Needham-Schroeder Protocol (variant)

Modified Challenge-Response (nonce and timestamp):

- C exchanges messages with both A and B
- timestamp t used only between B and C
- K session secret key

1. A chooses N and sends to B: <A, N>
2. B chooses N' and sends to C: <B, N', K_{BC}(N, A, t)>
3. C sends to A: <K_{AC}(B, N, K, t) , K_{BC}(A, K, t), N'>
4. A sends to B: <K_{BC}(A, K, t), K(N')>

Basis for the Kerberos protocol

Expanded Needham-Schroeder