Distributed Systems Security

Authentication Principles - 1

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Lecture Objectives

- Define authentication
- Identify types of protocols needed
- Identify threats
- Examine classic protocols based on SKC and identify weaknesses

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Authentication

- Assurance that messages are from claimed originator
- Generally implies that original message has not been tampered with - message integrity
- Does not necessarily imply secrecy

- **Mutual authentication:** Two parties satisfy themselves of each others identity usually for long term (session or transaction) interaction
- **One-way Authentication:** One party is authenticated, eg. your login to Unix

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Cryptography

- Use cryptography to achieve these functions
- Need keys to be distributed
- Key distribution different for PKC and SKC

- ∴Need Key Distribution Protocols
- ∴ Need PKC and SKC protocols
- Also, need message oriented (single-ended) protocols and stream oriented (two-way) protocols

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Basic Protocol Map

- We will use the following map to keep our bearings as we explore the various protocols

	Shared Key (SKC)	Public Key (PKC)
Key Distribution	Shared Key Distribution	Public Key Distribution
One-way Authentication	One-way SKC	**One-way PKC**
Two-way Authentication	Two-way SKC	**Two-way PKC**

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Notation

A, B	Principals - "good guys" eg. Alice, Bob
U, V	Domains - "organisations" eg. UCL, IBM
E	Eavesdropper - "bad guys", eg. Eve
S	Security server/service
Kx	Personal key of "x"
Ks	"Session" key
{Data}K	Data encrypted with key K

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SKC Key Distribution

- For A, B to communicate securely they need to share a key
- This could be achieved by:
  1. Providing pair-wise keys for all possible communications to all relevant parties
  2. Shared key selected by A and physically transmitted to B
  3. Third party selects key and physically delivers it to A and B
  4. If A and B already have secure communication, one party can select a new key and transmit using old key
  5. If A and B have secure communication to third party S. S can provide shared key via these secure connections

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SKC Key Distribution - 2

- For a population of N users, approach 1 requires N(N-1)/2 keys
- May be just about feasible for small populations, but e.g. N=1,000 needs about 500,000 keys and N=10,000 needs about 50M keys
- Also, keys used for long periods become more vulnerable to cryptanalysis, so would need to change them periodically/frequently
- Physical delivery is generally inappropriate for routine key distribution in distributed systems, ∴ 2 and 3 are not suitable

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SKC Key Distribution - 3

- Approach 4 can be used, but needs an existing secure session
- Approach 5 is attractive. It requires that S shares a key with each member of population
- Thus, need to distribute N-1 keys, not N(N-1)/2
- Hierarchy of keys:
  - Session keys
  - End user/application personal keys shared with first level KDC
  - Repeated for higher level KDCs

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Two-way SKC Authentication

- Assume A, B already have their own personal keys, Ka and Kb (do not know each other's key)
- Each key is shared with trusted third party, S, such that S knows private keys of both A and B
- S known as *Authentication Server (AS)* or *Key Distribution Centre (KDC)*
- Protocol needed to distribute session key securely and mutually authenticate A and B
- Note: A and B both trust S, since S holds their personal keys

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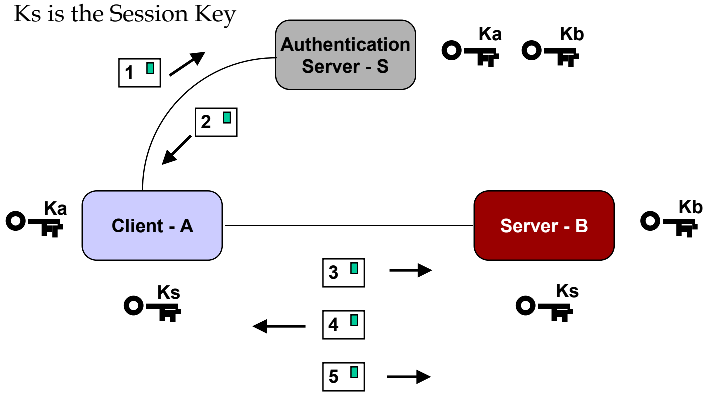
Two-Way Authentication

Protocol is broadly of form below

Ka, Kb are Personal Keys

Ks is the Session Key



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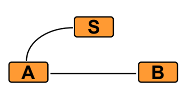
Needham & Schroeder SKC Protocol



- A, B are parties involved
- S is Authentication Server
- Ka, Kb are personal keys of A, B known only to owner and S
- I is "nonce" used once only
- Ks is "conversation key" or "session key" generated by S
- "," indicates message composition or concatenation

<u>Authentication with SKC</u>

1.	A->S:	A, B, Ia1
2.	S->A:	{Ia1, B, Ks, {Ks, A}Kb }Ka
3.	A->B:	{Ks, A}Kb
4.	B->A:	{Ib}Ks
5.	A->B:	{f(Ib)}Ks
6.	A<->B:	{Data}Ks

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Needham & Schroeder SKC Protocol - 2

- Steps 1 to 3 are used to distribute session key to A and B
- Step 3 also indicates to B that S has only distributed this key to A (and B)
- ∴ Steps 3 to 5 deal with mutual authentication and live-ness indicating to both parties that message 3 was not a replay
- Can extend it to deal with multiple domains (see over)
- KDCs use similar protocol with a super-KDC they all trust

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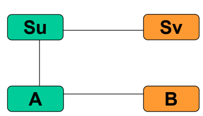
Needham & Schroeder Multiple Domains



- As before, plus:
- Su, Sv are Authentication Servers
- Ka, Kb are secret keys of A, B known only to owner & Su, Sv resp.
- Ksas is conversation key between authentication servers

Authentication with Secret Keys

1.	A->Su:	A, B, Ia1
1a.	Su->Sv:	{Ks, B, A, Ia1}Ksas
1b.	Sv->Su:	{{Ks, A}Kb, Ia1, A}Ksas
2.	Su->A:	{Ia1, B, Ks, {Ks, A}Kb }Ka
3.	A->B:	{Ks, A}Kb
4.	B->A:	{Ib}Ks
5.	A->B:	{f(Ib)}Ks

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Needham & Schroeder Protocol Issues

- What is purpose of nonce?
- What forms of attack are possible?
  - Simple replay
  - Backward replay
  - Nonce attacks

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Needham & Schroeder Weakness

- Simple replay of msg 3 to B by E may cause confusion at A if session has closed, but otherwise is relatively harmless
- However, if an old session key has been compromised and E can suppress selected messages to A, then replay of msg 3 will cause B to have session with E thinking it is A
- Denning suggested use of timestamps to overcome this
- Because nonces give no indication of freshness of message

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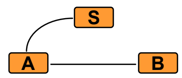
Denning SKC Protocol



- A, B are parties involved
- S is Authentication Server
- Ka, Kb are personal keys of A, B known only to owner and S
- T is timestamp
- Ks is "conversation key" or "session key" generated by S
- "," indicates message composition or concatenation

Authentication with SKC

1. A->S:	A, B
2. S->A:	{T, B, Ks, {Ks, A, T}Kb }Ka
3. A->B:	{Ks, A, T}Kb
4. B->A:	{Ib}Ks
5. A->B:	{f(Ib)}Ks
6. A<->B:	{Data}Ks

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Denning SKC Protocol - 2

- Basically same protocol as Needham &Schroeder, except timestamp generated by S used instead of nonce
- Message considered valid if on receipt:
  $|Clock - T| < \Delta t1 + \Delta t2$
  where
  - $\Delta t1$ is max. allowed discrepancy between KDC and local clock
  - $\Delta t2$ is max. network delay
- Provided B's personal key not compromised, only replay of message 3 is possible and timestamp thwarts this attack

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Denning Protocol Issues

- Clocks must be synchronised, so need secure clock synchronisation protocol
- If recipient clock can be advanced, accidentally or by sabotage, protocol messages could be replayed again at a valid time
- Frequent clock synchronisation with KDC is one solution

- Neuman and Stubblebine [1993] proposed protocol to remove this requirement using nonces again

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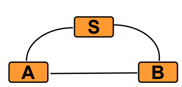
Neuman and Stubblebine SKC Protocol



- A, B are parties involved
- S is Authentication Server
- Ka, Kb are personal keys of A, B known only to owner and S
- Tb is time limit for session key
- Ia, Ib are nonces
- Ks is "conversation key" or "session key" generated by S
- "," indicates message composition or concatenation

Authentication with SKC

1. A->B:	A, Ia
2. B->S:	B, Ib, {A, Ia, Tb}Kb
3. S->A:	{B, Ia, Ks, Tb}Ka, {A, Ks, Tb}Kb, Ib
4. A->B:	{A, Ks, Tb}Kb, {Ib}Ks
5. A<->B:	{Data}Ks

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Neuman and Stubblebine SKC Protocol - 2

- Impervious to clock sabotage or session key cracking
- Assumes Ka and Kb not compromised

- Nonce Ia is bound to Ks within short space of time via protocol synchronisation not clock sync.
- Similarly, Ib is bound to Ks
- Tb provides a validity period for the session key
- {A, Ks, Tb}Kb acts as a ticket or authenticator for A with B, indicating session key and validity period

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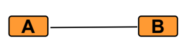
Neuman and Stubblebine SKC Protocol - 3



- Can avoid repeated KDC exchanges by use of ticket within validity period
- Tb is relative to B's clock so no clock sync. issue

Creation of new session

1. A->B:	{A, Ks, Tb}Kb, Ia'
2. B->A:	Ib', {Ia'}Ks
3. A->B:	{Ib'}Ks
4. A<->B:	{Data}Ks

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Single-ended Authentication

- In some applications parties are not necessarily available simultaneously, e.g. e-mail
- Ideally, we would like to have mutual authentication so that A knows only B can read message and B knows that it could only have come from A
- If not possible to have 2-way dialogue, assurances may be weaker
- Note: this is not strictly one-way authentication

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Needham & Schroeder Single-ended Authentication

- Single-ended system, e.g. e-mail
- As before, plus:
- TS is sender's timestamp
- Sn is serial number of message fragment

- Recipient must check for possible replays (via max. clock asynchrony and estimated delivery delay)

Authentication with Secret Keys

1. A->S: A, B, Ia1
2. S->A: {Ia1, B, Ks, {Ks, A}Kb }Ka
3. A->B: {Ks, A}Kb, {TS,S1, Mess1}Ks, {S2,Mess2}Ks, ..

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E-mail Protocols

- This can form the basis of secure e-mail protocols
- However, e-mail is often distributed by the originator to several recipients so there are additional threats and additional service requirements
- What might they be?
- See Pretty Good Privacy (PGP) and Privacy Enhanced Mail (PEM) for more details

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Further Reading

- W Stallings, "Cryptography and Network Security: Principles and Practice", 2ed, Prentice Hall, 1999, 0-13-869017-0
  - **Key Distribution:** pp 141-149
  - **Authentication:** pp 303-311
  - **Pretty Good Privacy:** pp 356-374
- C Pfleeger, "Security in Computing", 2ed, Prentice Hall, 1997, 0-13-185794-0
  - **Privacy Enhanced Mail:** pp 422-426

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Further Reading - 2

- R Needham & M Schroeder, “Using Encryption for Authentication in Large Networks of Computers”, CACM, Dec 1978
- D Denning, “Cryptography and Data Security”, Addison-Wesley, 1982
- B Neuman & S Stubblebine, “A Note on the use of Timestamps as Nonces”, ACM Operating Systems Review, 1993