Designing secure multiple-server authentication schemes

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Content

Significant technologies

- **Internet of Things (IoT)**
  2018 $772 billions are spent on IoT devices
- **Edge computing**
  Edge computing broadly as all computing outside the cloud happening at the edge of the network, and more specifically in applications where realtime processing of data is required.
- **Cloud computing**
  Several advantages (cost savings, scalability, robustness, etc.)
- **Smart home, city**
  Savings, safety, convenience, and control.

Security challenges

Fears of internal and external attackers

- Data is available to service providers -clouds
- "Optimizing" production at the expense of security - IoT
  Resource constrained devices
- Human risks
  - Poor security
    Most devices use weak or default passwords.
  - Poor maintenance
    After the initial setup, users do not use the devices properly (update).
- These systems and devices are common targets of cyber attackers.
  - Different types of external attacks
  - Zombie networks, DoS attacks, MITM,Brute Force, etc.
  - Several incidents: Mirai and other Botnets (dictionary attack)

Definitions

- Entity authentication
  The protocol by which one entity is assured of the identity of a second entity.
  Folláth J, Huszti A, Pethő A, "**DESignIn Asymmetric Authentication System**", ICAI 2007 Eger, Magyarország, pp. 53-61. , 9 p.
- Cryptographic protocol
  It is a system of rules that allow two or more entities of a communications system to transmit information via any kind of variation of a physical quantity and accomplish one or more security goals.
- Mutual authentication
  In mutual authentication parties who engage in a conversation in which each gains confidence that it is the other with whom he speaks.
- Key agreement
  Both entities contribute to the joint secret key by providing information from which the key is derived.
- Authenticated key agreement protocol
  A key exchange protocol that provides mutual implicit key authentication is called an authenticated key agreement protocol (AK protocol).

Concept of Distributed Authentication

Centralized structure

- There are fears about the centralized structure
- Central databases are primary targets for hackers
- If these databases are compromised it cause huge damage.
- A single point of failure occurs typically in single-server solutions.
  If the server is unavailable, the provider usually needs to ensure replication to tackle the failure of their servers.
- Golden Ticket Attack, OneLogin attack

Distributed Authentication

- External attackers have to attack multiple servers simultaneously, which increases the attack cost.
- If one or more servers break down or become corrupt, the service provider is able to service and authenticate the users securely.

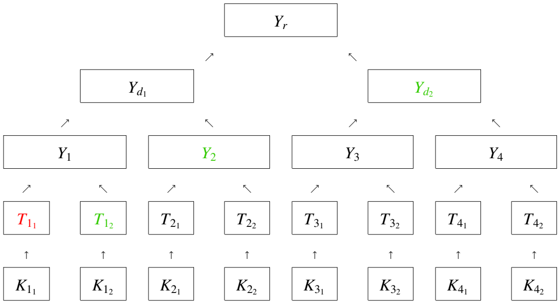
Security goals designing authenticated key agreement protocol

- **Correctness**: Participants will always accept the same symmetric key.
- **Key secrecy**: In the presence of an active attacker, the symmetric key can be calculated only by the participants.
- **Known-key security** (Freshness): Each protocol run results in a unique secret symmetric key. A compromised symmetric key is not able to provide information about other symmetric keys.
- **Mutual authentication**: Mutual authentication prevents an attacker from impersonating a legitimate participant and illegally accessing user information.
- **(Perfect) Forward-secrecy**: It holds if long-term secrets of one or more entities are compromised and **the secrecy of previous session keys is not affected.**

One-Time Password Authentication and Key Exchange for Cloud Environment

- Two-factor authentication
  static password + one-time password
- Malicious insiders
  distributed authentication among cloud servers, one-time password is stored distributed
- MAC key exchange
  providing data origin integrity
- Improving efficiency

Merkle-tree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One-Time Password Authentication and Key Exchange for Cloud Environment

Andrea Huszti and Norbert Oláh. "**A simple authentication scheme for clouds.**" 2016 IEEE Conference on Communications and Network Security (CNS). IEEE, 2016.

Andrea Huszti and Norbert Oláh. "**DECAP-Distributed Extensible Cloud Authentication Protocol**" 2nd CRYPTACUS Workshop 16-18 November 2017 Radboud University, Nijmegen The Netherlands (https://cryptacus. cs. ru. nl). 2017.

Andrea Huszti and Norbert Oláh. "**Security analysis of a cloud authentication protocol using applied pi calculus.**" International Journal of Internet Protocol Technology 12.1 (2019): 16-25.

Identity-based cryptography

- Certificate-based:

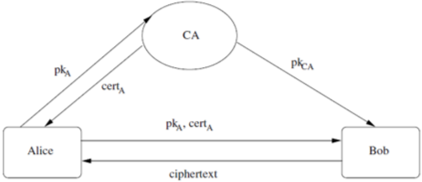

Fig. 1.9 Certifying authority and trust in public key.

- Identity-based:

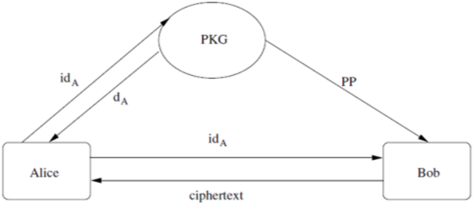

Fig. 1.10 An overview of an IBE scheme.

Bilinear map

Definition

Let G_1 and G_2 be two groups of order q for some large prime q. A map $e : G_1 \times G_1 \rightarrow G_2$ is an admissible bilinear map if satisfies the following properties:

1. Bilinear: We say that a map $e : G_1 \times G_1 \rightarrow G_2$ is bilinear if $e(aP, bQ) = e(P, Q)^{ab}$ for all $P, Q \in G_1$ and all $a, b \in Z$.
2. Non-degenerate: The map does not send all pairs in $G_1 \times G_1$ to the identity in G_2. Since G_1, G_2 are groups of prime order, if P is a generator of G_1 then $e(P, P)$ is a generator of G_2.
3. Computable: There is an efficient algorithm to compute $e(P, Q)$ for any $P, Q \in G_1$.

Bilinear Diffie-Hellman Problem

Definition

Let $e : G_1 \times G_1 \rightarrow G_2$ be a bilinear map on (G_1, G_2) and $a, b, c \in Z_q^*$. Given (P, aP, bP, cP), compute $e(P, P)^{abc}$.

Identity-based cryptography

- Gábor Kovács and Attila Pethő. "**Személyre szabott titkosítási rendszerek megvalósítása**" (2014)
- Lilla Nyakacska and Andrea, Huszti. "**Elliptikus görbék és bilineáris párosítások**" (2016)
- Andrea, Huszti and Norbert Oláh. "**Identity-Based Cloud Authentication Protocol.**" THE 11TH CONFERENCE OF PHD STUDENTS IN COMPUTER SCIENCE. 2018.
- Ádám, Vécsi, Attila Bagossy, and Attila Pethő. "**Cross-platform Identity-based Cryptography using WebAssembly.**" Infocommunications (2019): 31. - (SETIT project)
- Szilárd Dávid Szürti and Botond Mezei "**Attribute-based Encryption WASI-alapú platformfüggetlen implementációja**" - TDK (2020) (SETIT project) Supervisors: Attila Bagossy and Ádám Vécsi

Provably Secure Scalable Distributed Authentication for Clouds

- Shared secret key between two or more entities
- Take advantages of the distributed system — distributed authentication
  - Robustness, scalability and greater availability
- Authenticated key exchange:
  - Password-based
  - Key agreement and key confirmation between the parties
  - Provably secure protocol
  - Efficiency

Theorem

Theorem

The proposed protocol is a secure AKC protocol in the random oracle model, assuming MAC is existentially unforgeable under an adaptive chosen-message attack and symmetric encryption scheme is indistinguishable under chosen plaintext attack, moreover ECCDH assumption holds in the elliptic curve group.

Proof Consider an adversary $\mathcal{A}$ and suppose that

$$Pr[\texttt{No-Matching}^{\mathcal{A}}(\kappa)]$$

is non-negligible. There are two cases: either the edge or the client oracle is accepted.

Security assumption of the symmetric encryption

- $n_C(\kappa)$ indicates the probability of an event that the attacker is successful
- Suppose that a client oracle is accepted — a server oracle is impersonated by the attacker
- Generating an $\mathcal{F}$ polynomial-time algorithm to break the symmetric encryption scheme is *indistinguishable under chosen plaintext attack*

$$\xi_2(\kappa) = \frac{n_C(\kappa)}{T_1(\kappa) T_2(\kappa) \binom{T_2(\kappa)-1}{k-1} T_3(\kappa)} - \lambda(\kappa),$$

- It contradicts the security assumption of the symmetric encryption

Provably Secure Scalable Distributed Authentication for Clouds

Andrea Huszti and Norbert Oláh. **Provably Secure Authenticated Key Agreement with Key Confirmation for Distributed Systems**, (2019), Proceedings of 14th International Conference for Internet Technology and Secured Transactions (ICITST-2019), pp:69-75.

Andrea Huszti and Norbert Oláh. (2020) **Provably Secure Scalable Distributed Authentication for Clouds**. In: Krenn S., Shulman H., Vaudenay S. (eds) Cryptology and Network Security. CANS 2020. Lecture Notes in Computer Science, vol 12579. Springer, Cham. pp 188-210 https://doi.org/10.1007/978-3-030-65411-5_10

NEMZETI KUTATÁSI, FEJLESZTÉSI
ÉS INNOVÁCIÓS HIVATAL

AZ INNOVÁCIÓ LENDÜLETE

AZ NKFI ALAPBÓL
MEGVALÓSULÓ PROJEKT

Project ID: 2018-1.2.1-NKP-2018-00004

Thank you for your attention!

Identity-based encryption

IBE: $(SetUp, Key, Enc, Dec)$

- *SetUp*
  output: (PP, msk),
  $PP = (\mathcal{P}, \mathcal{C}, \mathcal{I}, mpk)$ public parameters and *msk* a master secret key
- *Key*
  input: $id \in \mathcal{I}$ public key, PP, msk
  output: d_{id} secret key
- *Enc*
  input: $id \in \mathcal{I}, m \in \mathcal{P}, PP$
  output: $c \in \mathcal{C}$
- *Dec*
  input: $c \in \mathcal{C}, id \in \mathcal{I}, d_{id}, PP$
  output: $m \in \mathcal{P}$