PacSec2008 at Aoyama Diamond Hall

Behavior-based countermeasure against SSH Brute Force Attack

2008.11.13

TOMOYO Linux Project

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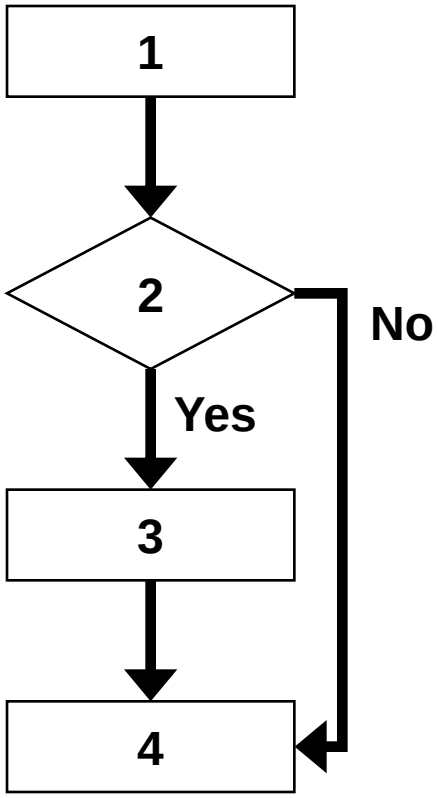
Preface

- The SSH service, which is used for remote administration, can allow the attacker to leak secrets and/or trojan the system if the attacker successfully logged into the system.
  - Recently, the attacks are becoming more and more complicated and sophisticated, and sometimes defeats traditional defense approaches.
- This presentation demonstrates a brand new defense approach using "Operating Systems with Advanced Access Control Features".
  - I use TOMOYO Linux as an example of such OS.

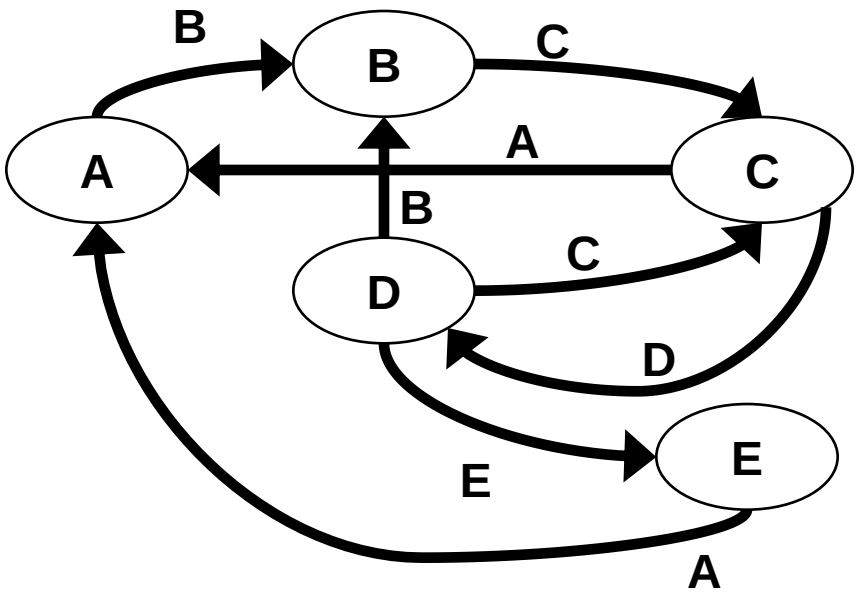
Preparative: Flow Chart

- You know what this diagram is, don't you?



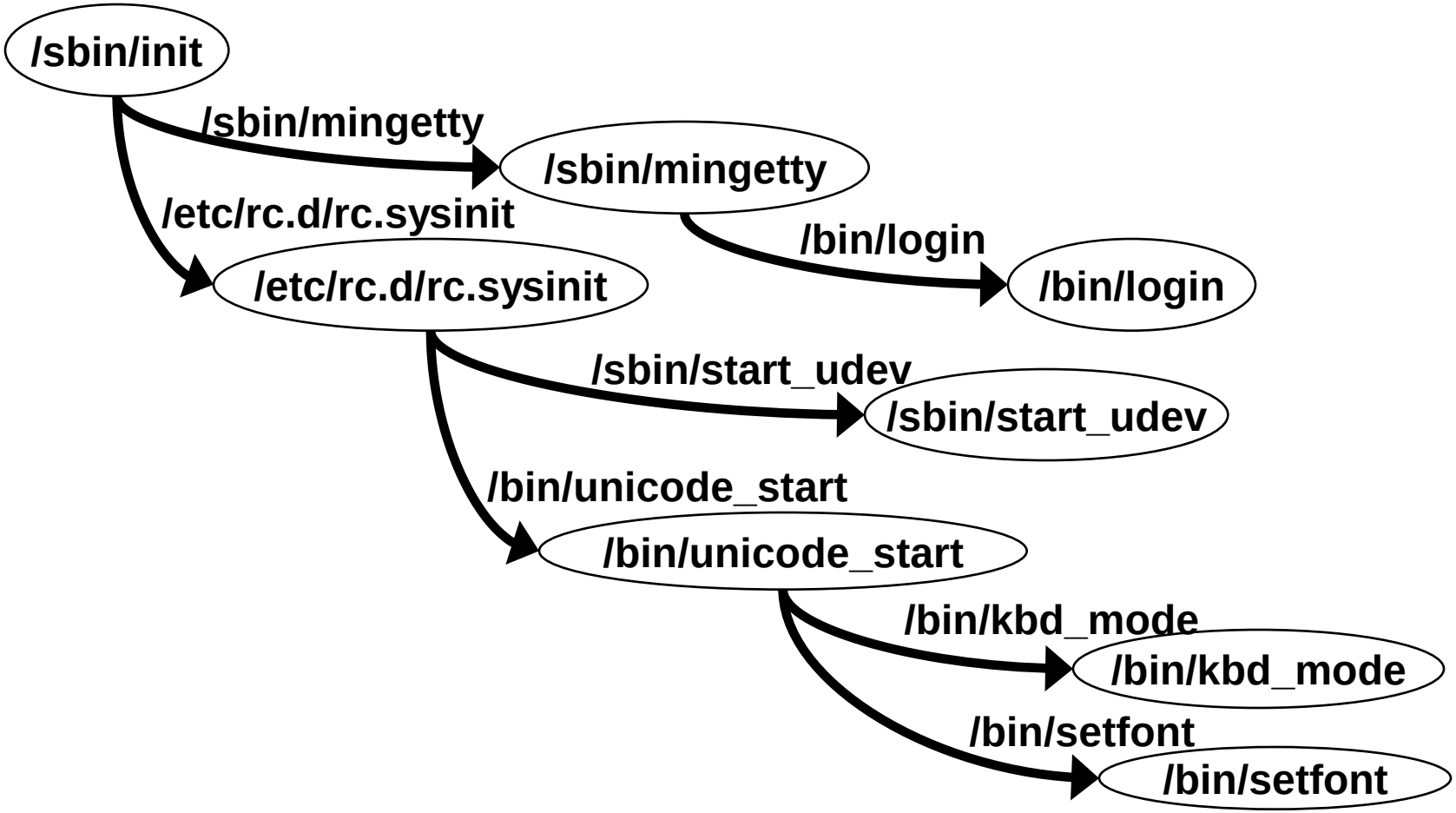
Preparative: State Transition Diagram (STD)

- You know what this diagram is, don't you?



Preparative: Example of STD in Linux

- Spreads like a tree from /sbin/init .

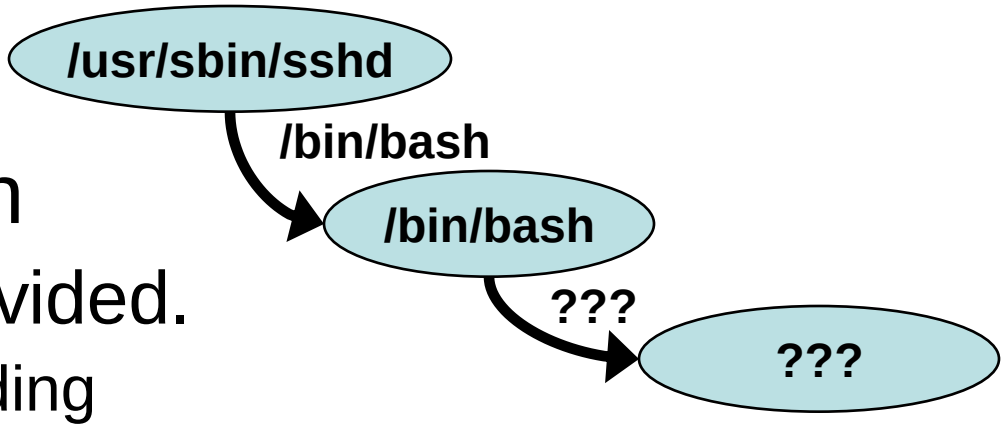


Preparative: What is TOMOYO Linux?

- A tool for designing and enforcing STD.
  - Monitors and judges program execution requests issued by userland applications.
  - Performs state transition by execution of a program.
- A tool for observing and restricting requests within each state.
  - Monitors and judges file's read/write requests issued by userland applications.
  - Updates process's internal state by read/write/execute requests issued by userland applications.

Preparative: Type of SSH sessions

- Interactive shell session
  - A shell is provided and the user can enter commands freely.
    - The user can access resources freely.
- Non-interactive shell session
  - Only commands passed to a shell's "-c" option are executed.
    - scp and/or sftp
- Non shell session
  - A shell is not provided.
    - TCP port forwarding



Conventional approaches

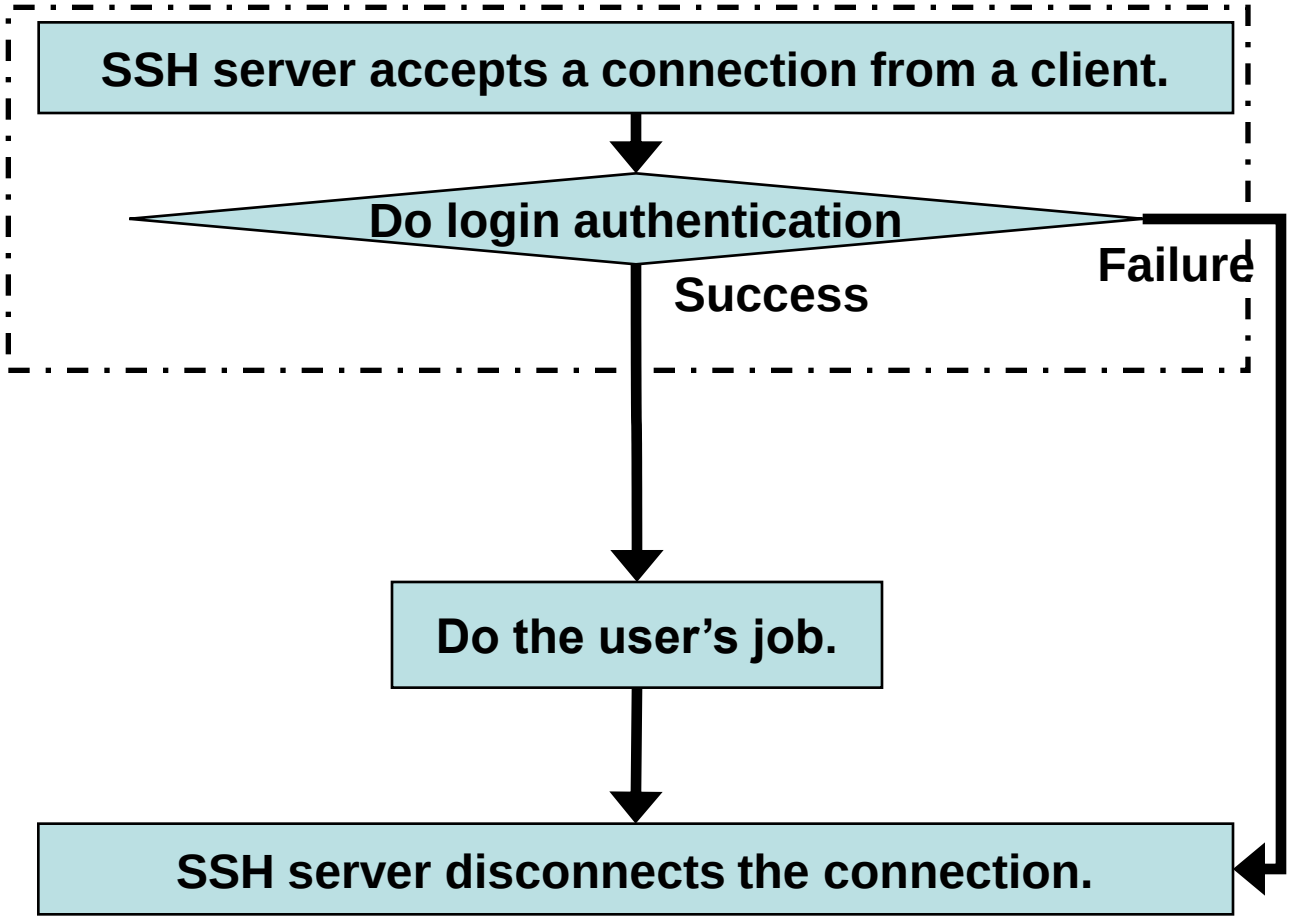
- Authentication based on "What the user knows".
  - Thus, subjected to brute-force attacks.
- Assumes that login authentication is not run through.
  - Reduce possibility of being run through.
    - Banning failed clients for some period using firewalls.
    - Using public-key authentication.
  - Brute force attacks are getting distributed and secret-key are stolen by malwares.

Proposed approach

- Authentication based on "How the user acts".
  - Utilize state transition.
- Assumes that login authentication is run through.
  - Restricts after conventional login authentication.
  - Just gives the user a login shell and observes whether the user acts as expected or not.
    - Something like probation in employment contract.

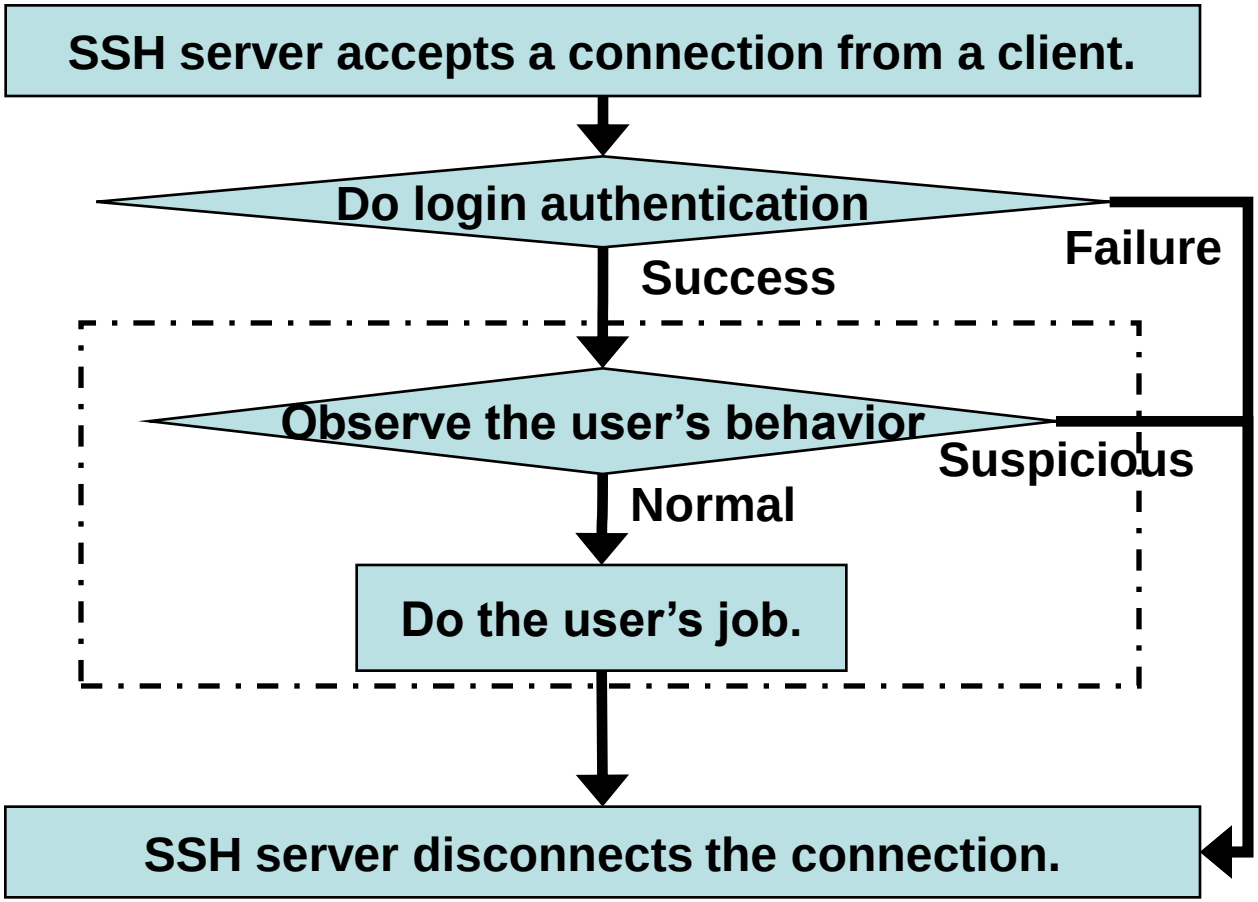
Flow of conventional approaches

- Customizes until the login authentication.



Flow of proposed approach

- Customizes after the login authentication.

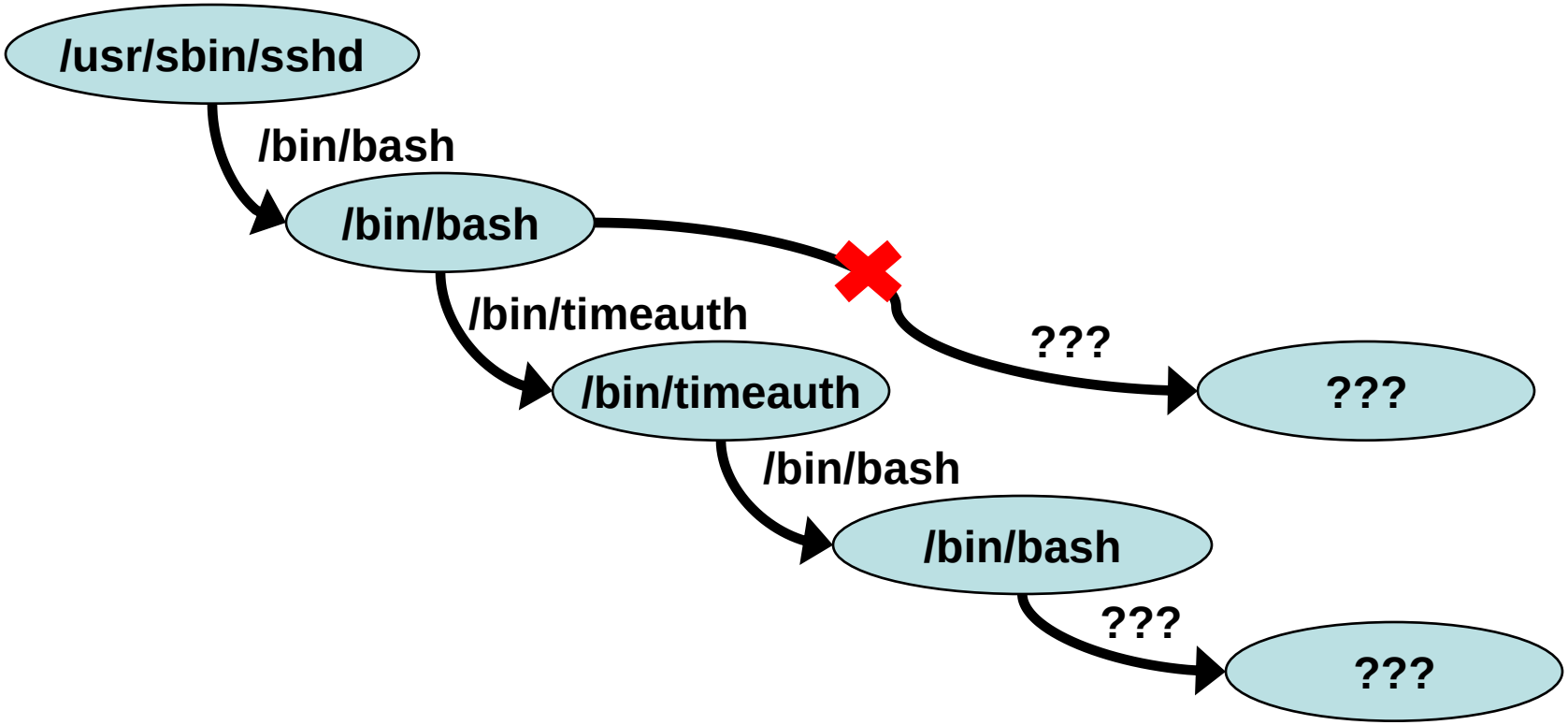


Open the door!

- Don't be a slave to convention.
  - Nothing is taboo.
  - Implement your own ideas.
- The gate now opens.
  - Welcome to
    the secure world!

Case 1: Interactive shell session

- Utilize typing timing.
  - What we need
    - own program /bin/timeauth



Case 1: Interactive shell session

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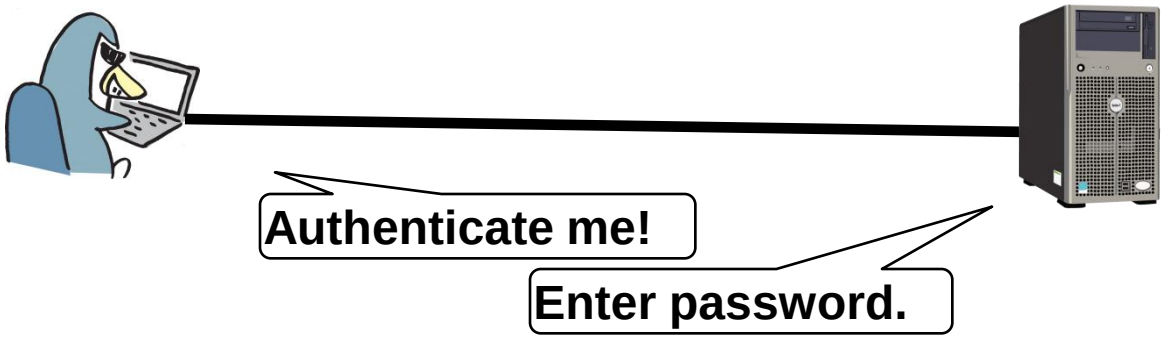

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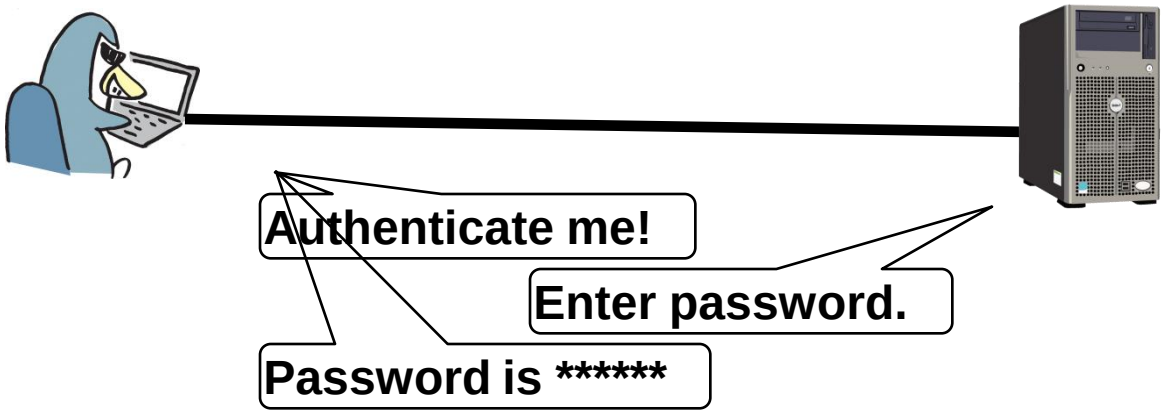

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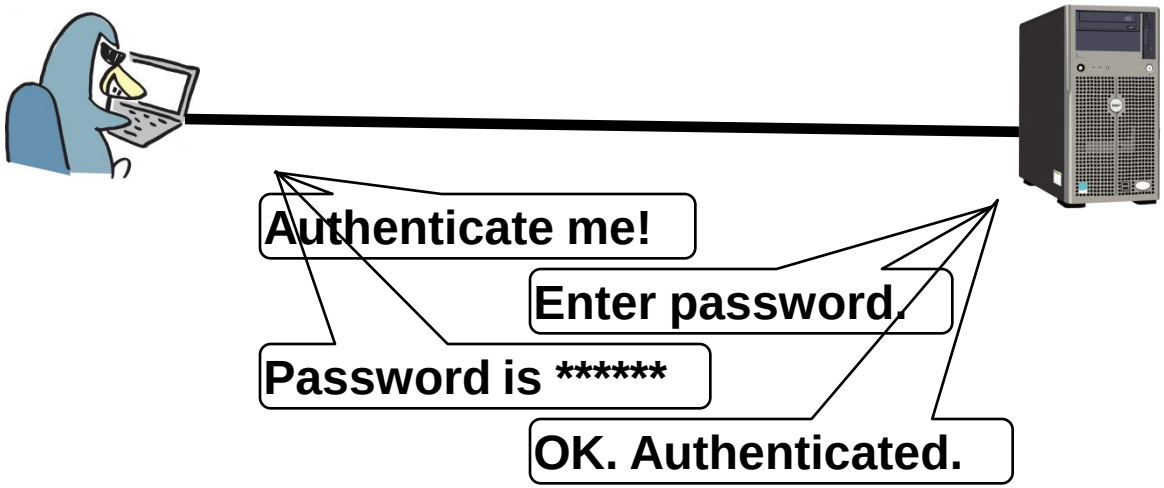

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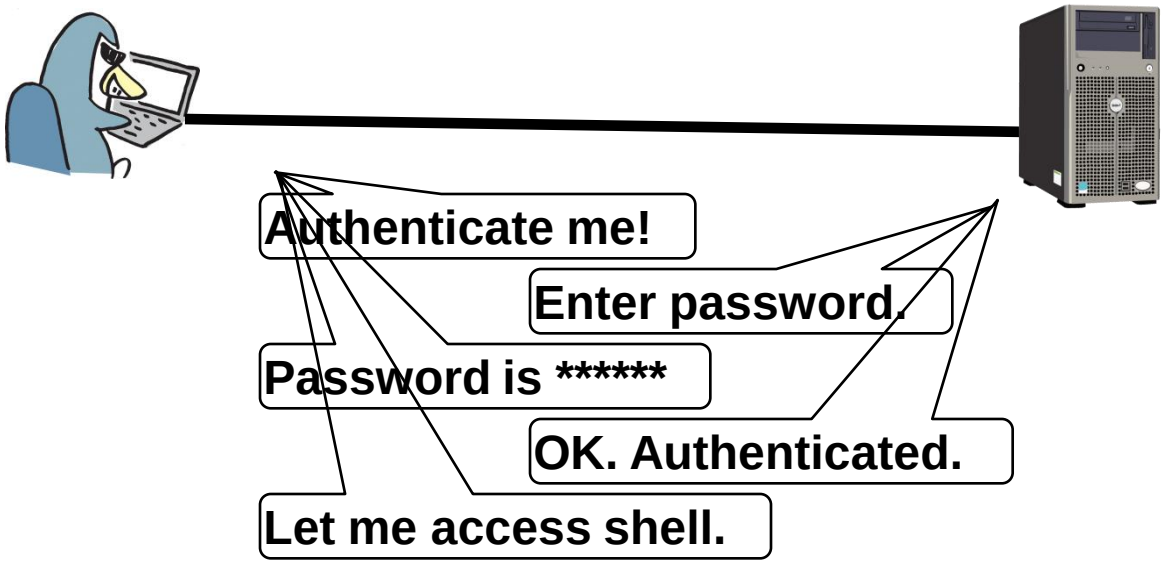

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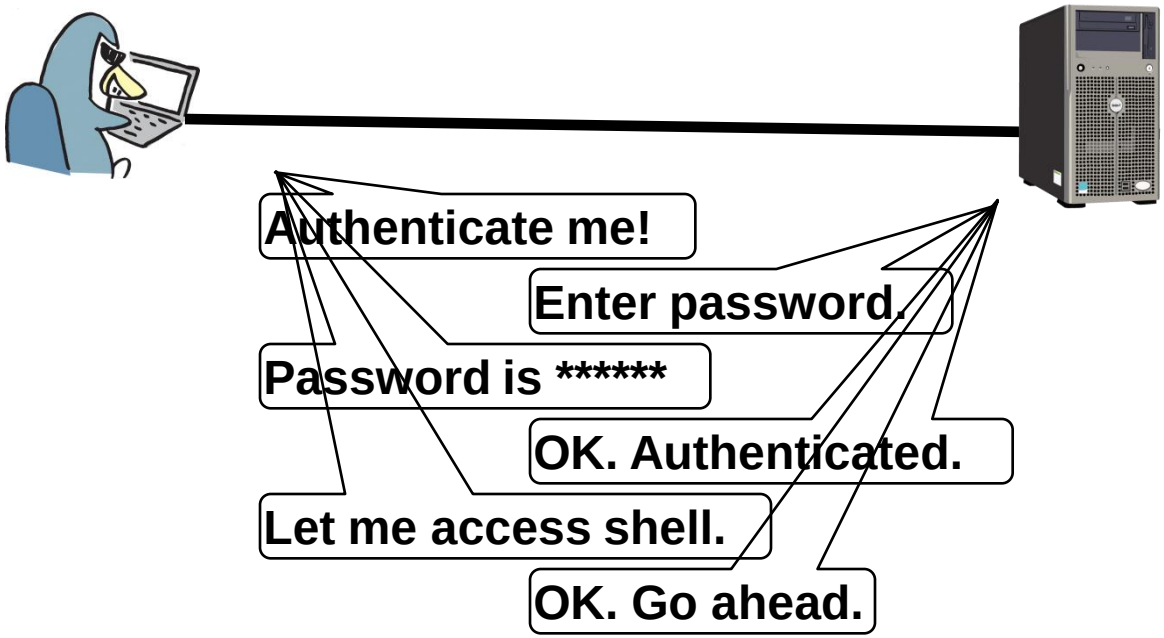

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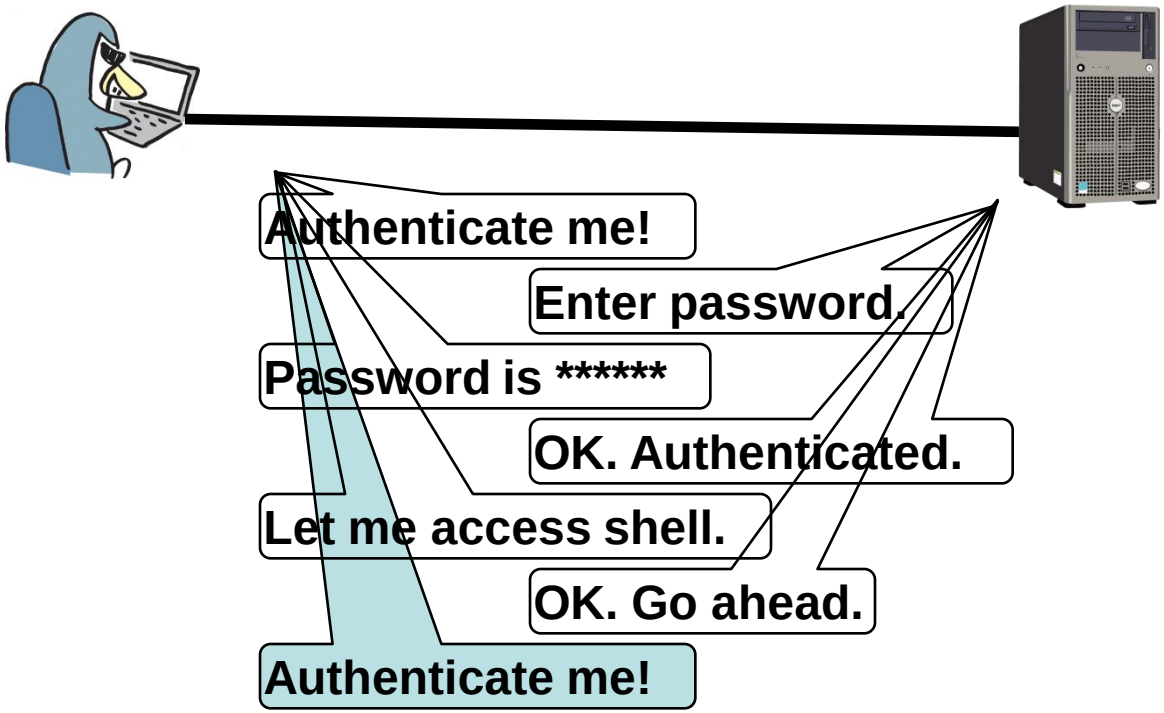

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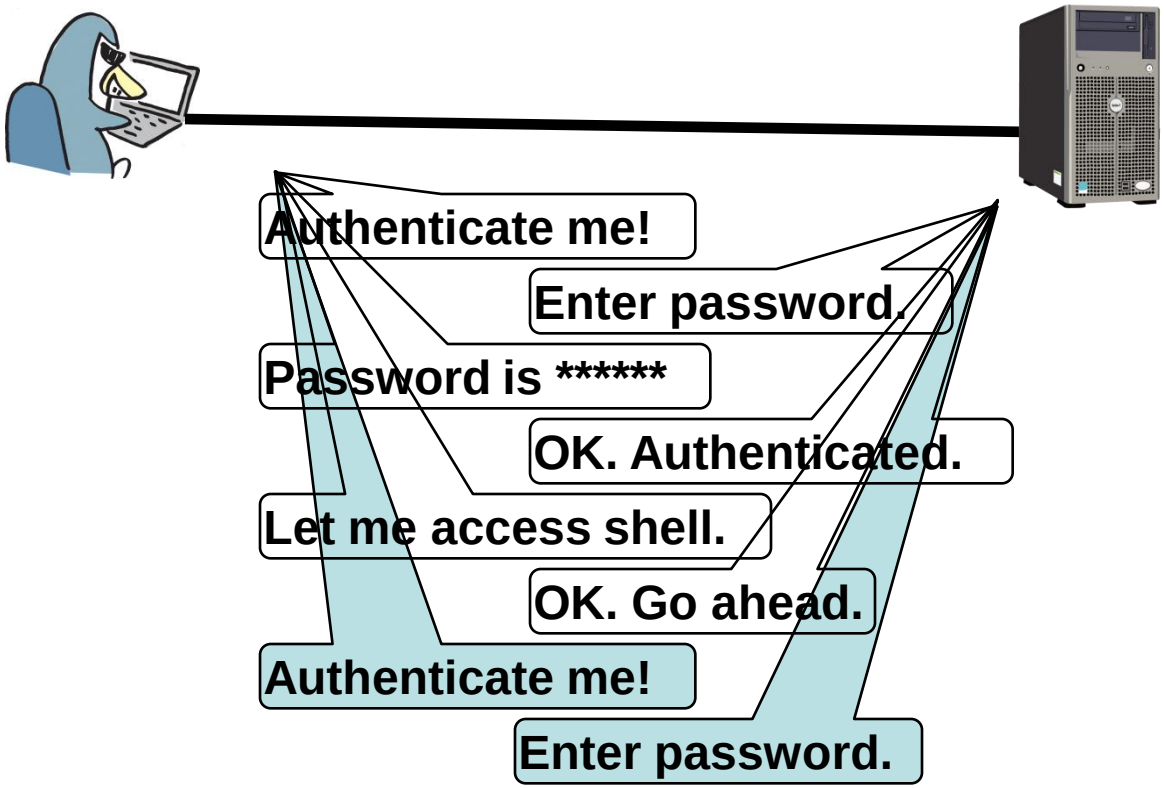

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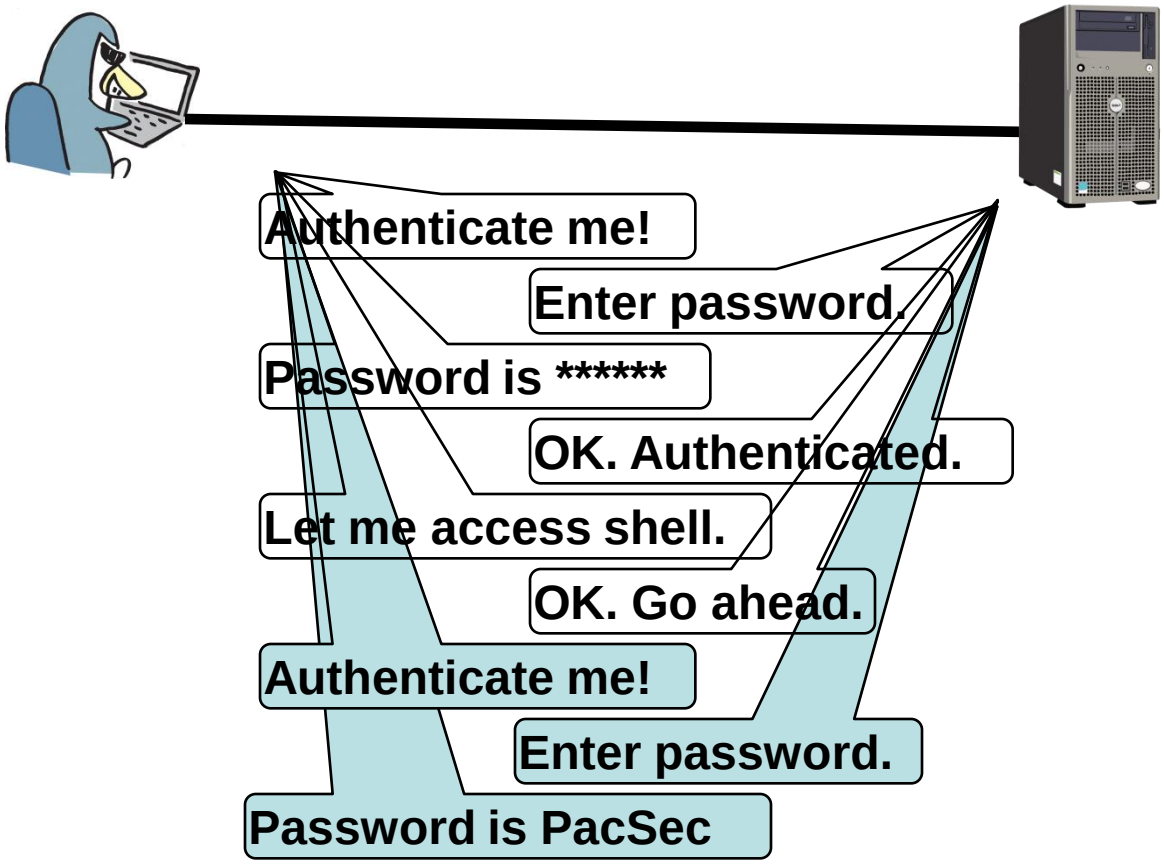

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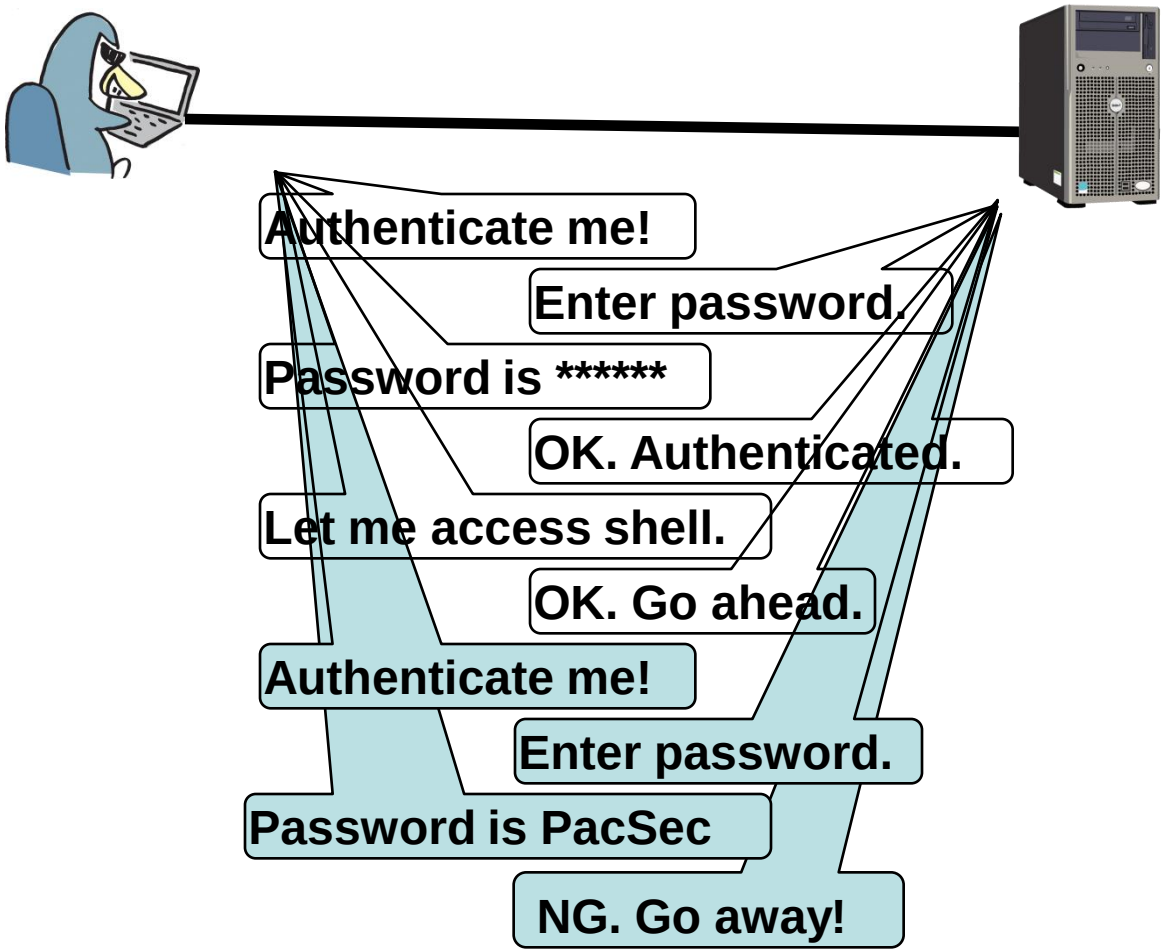

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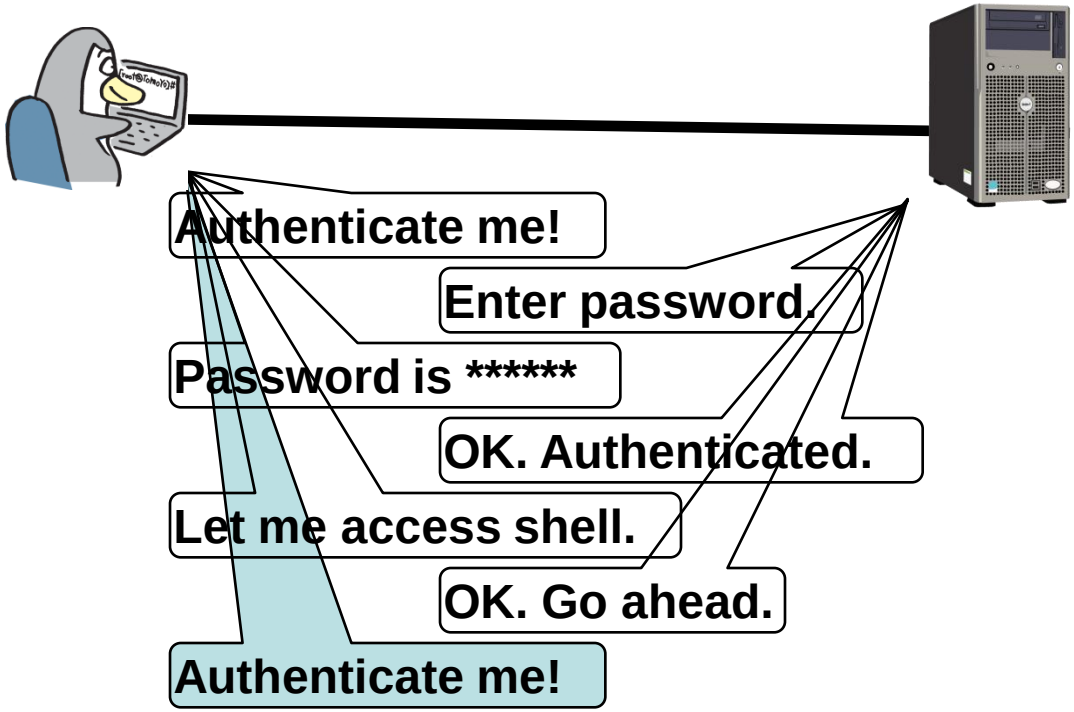

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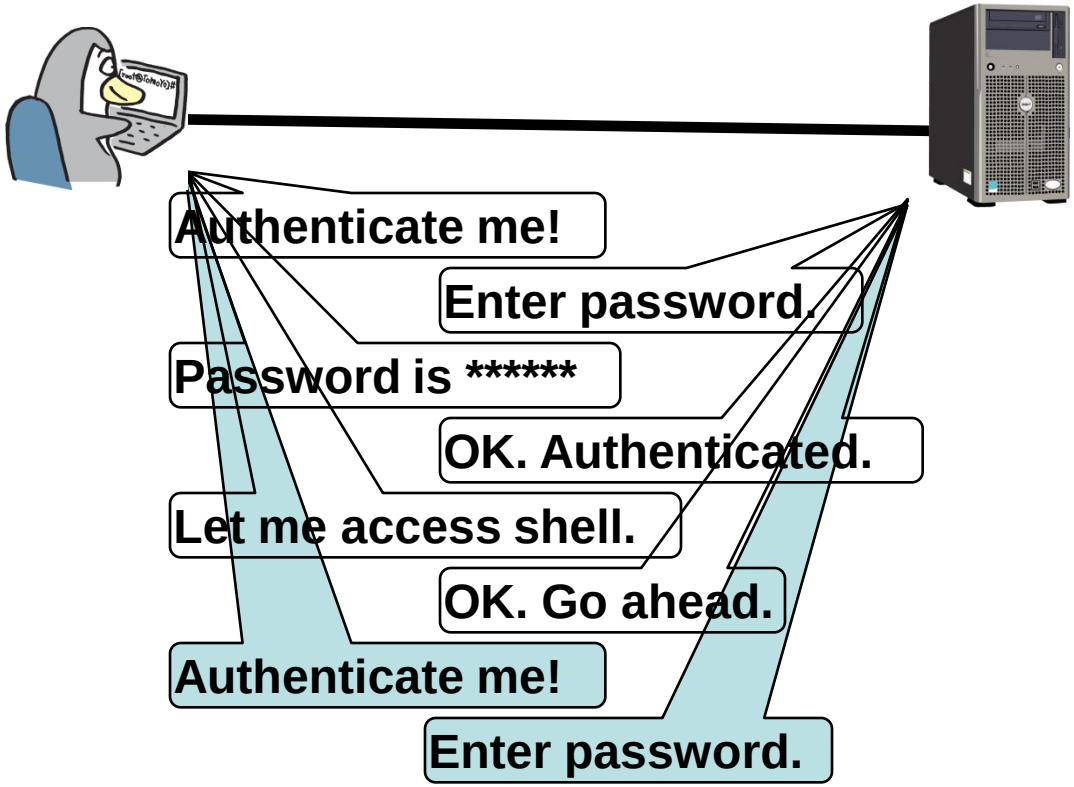

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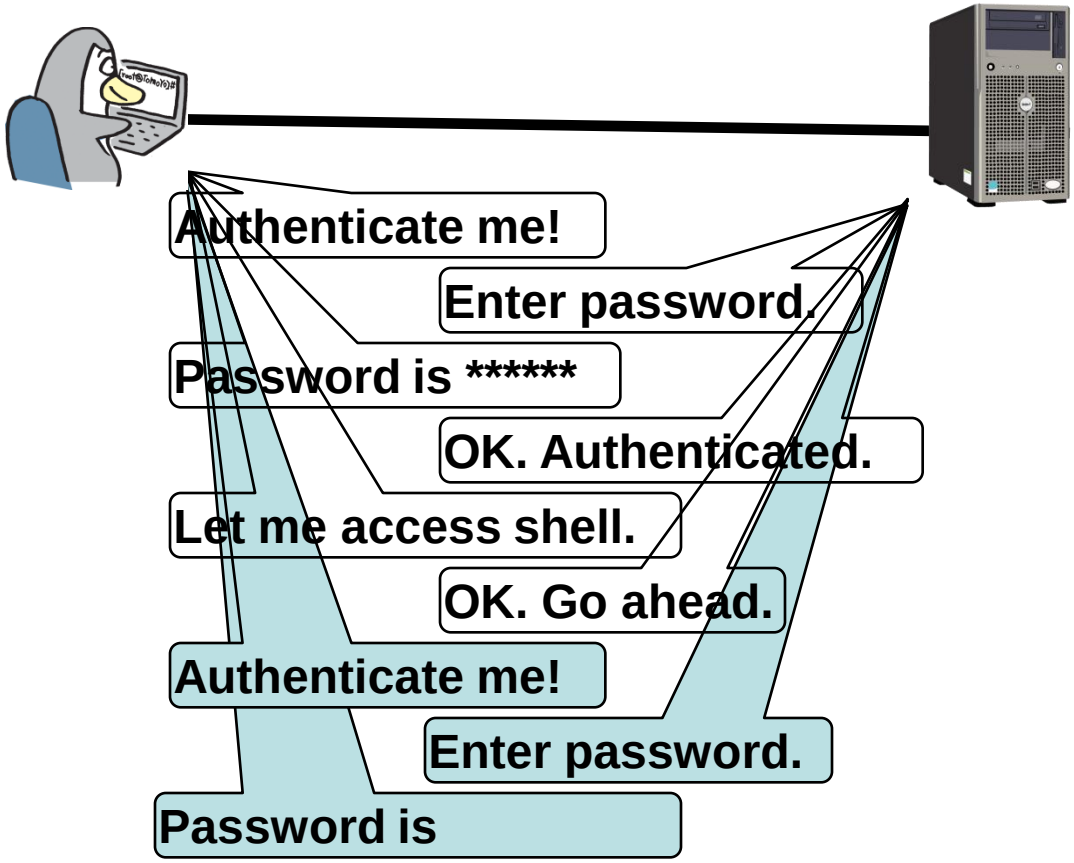

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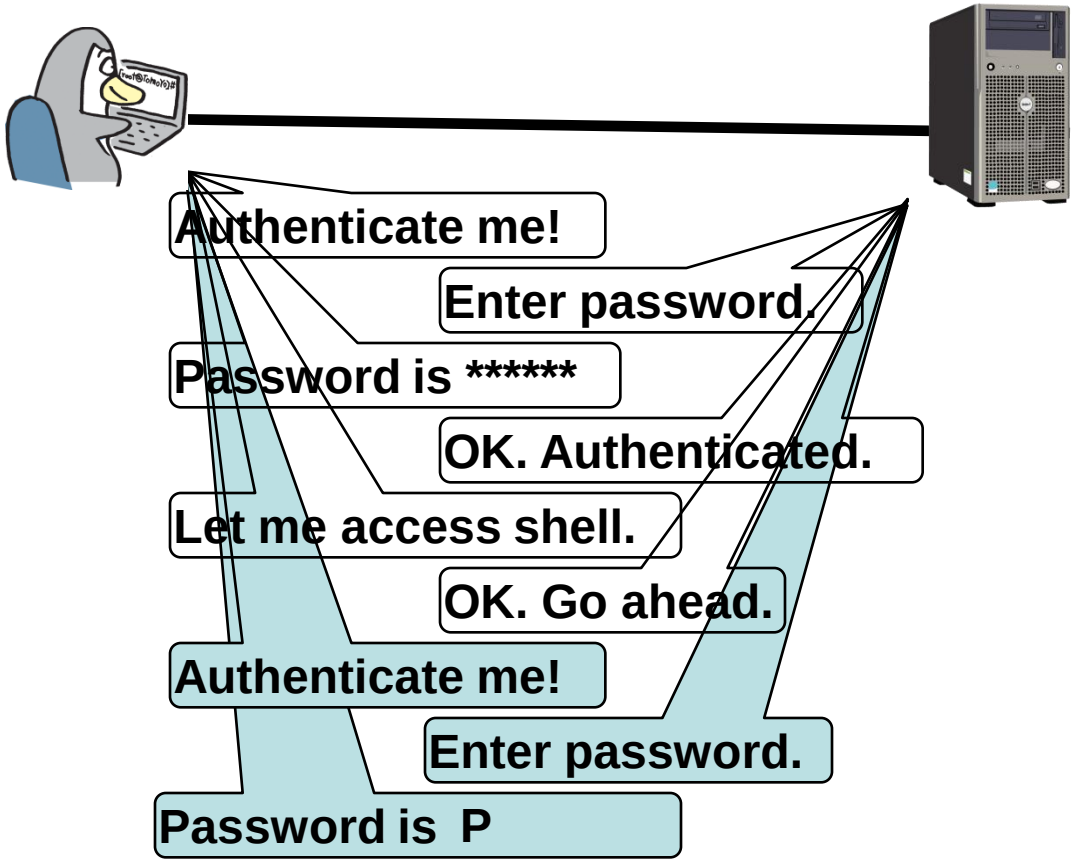

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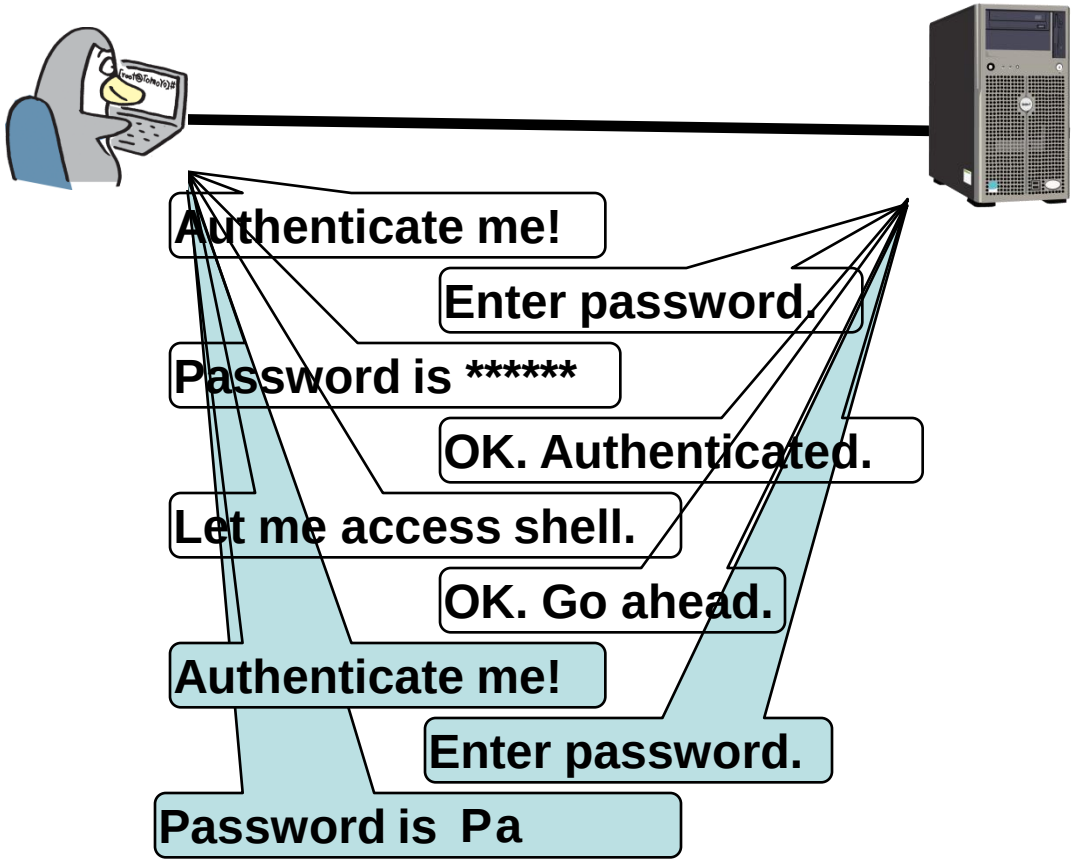

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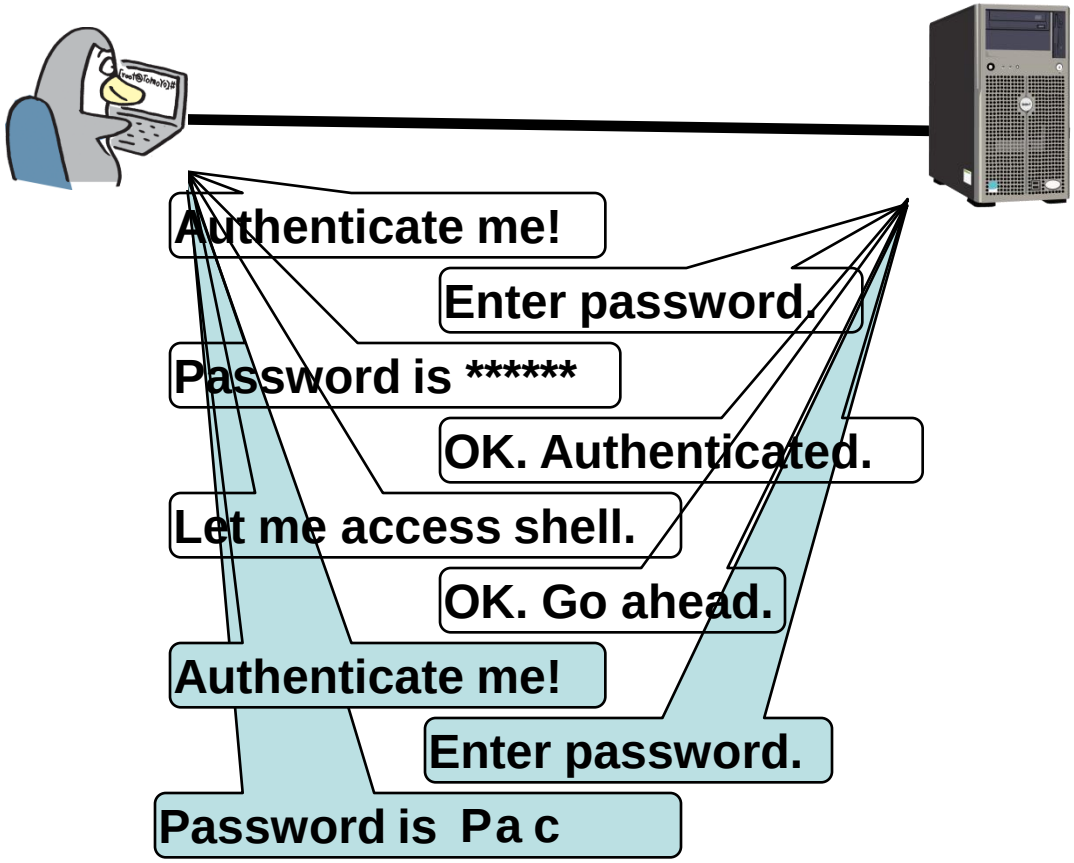

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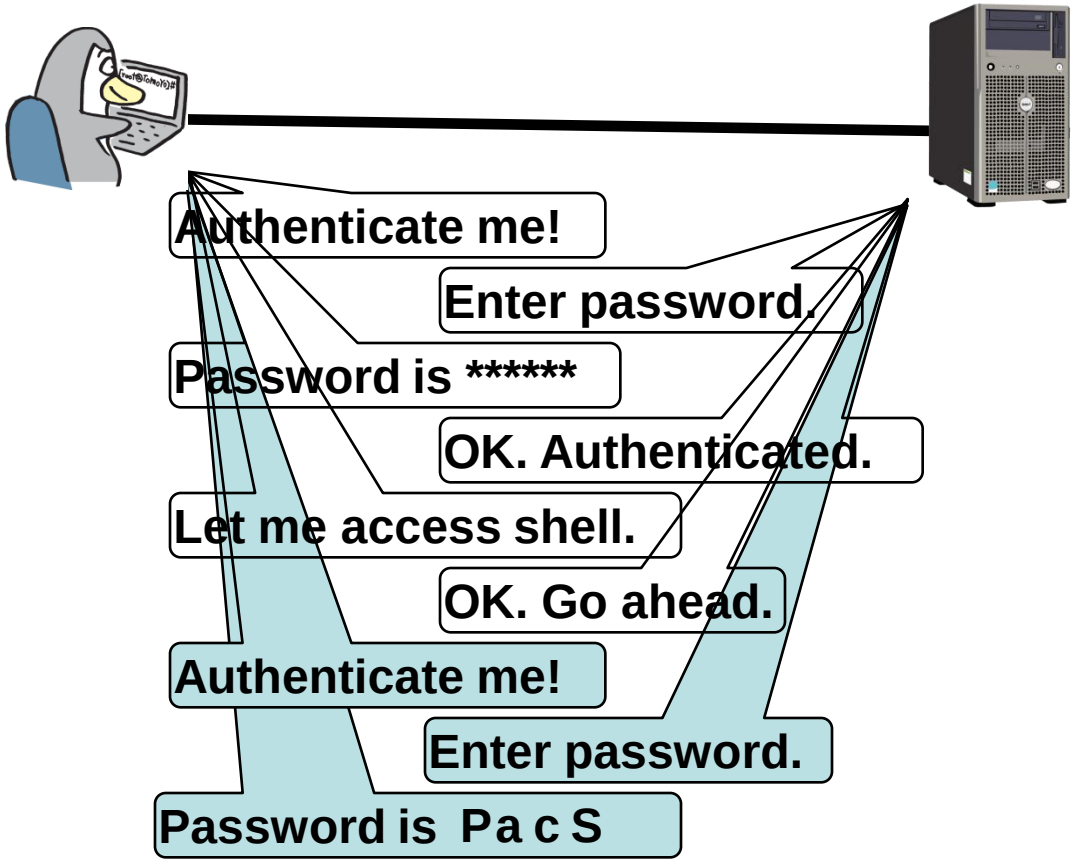

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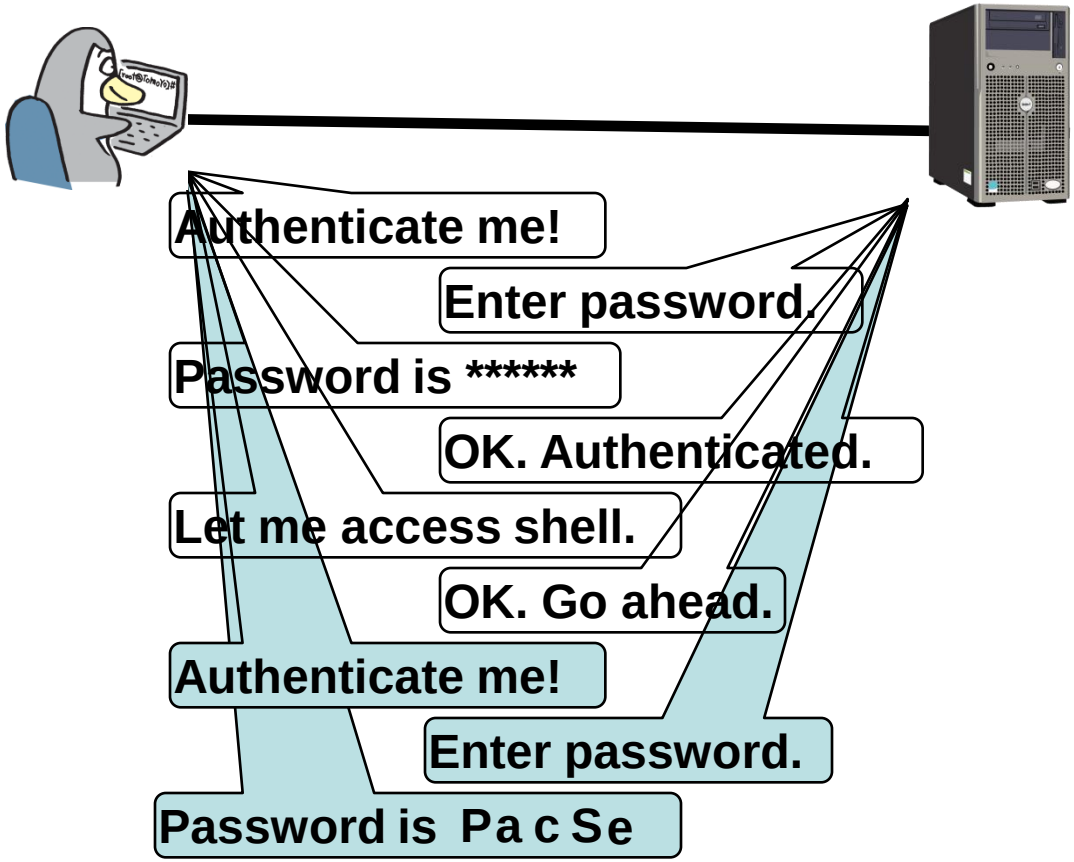

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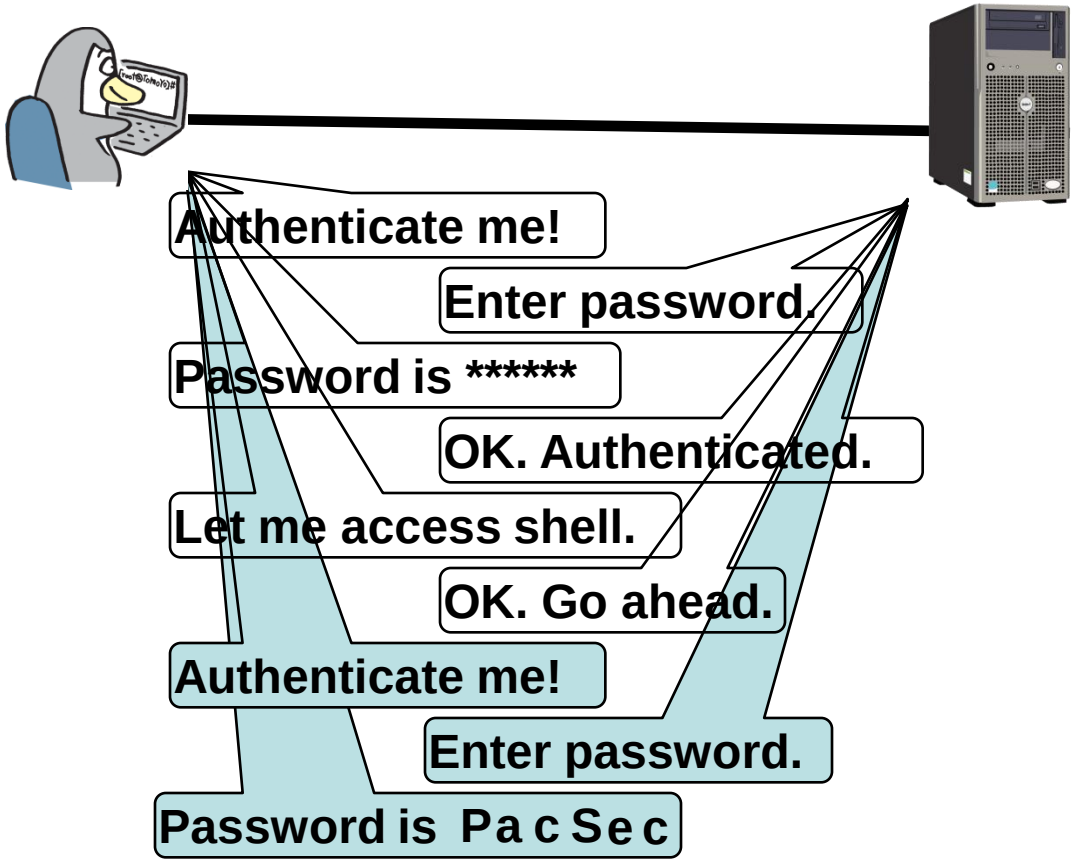

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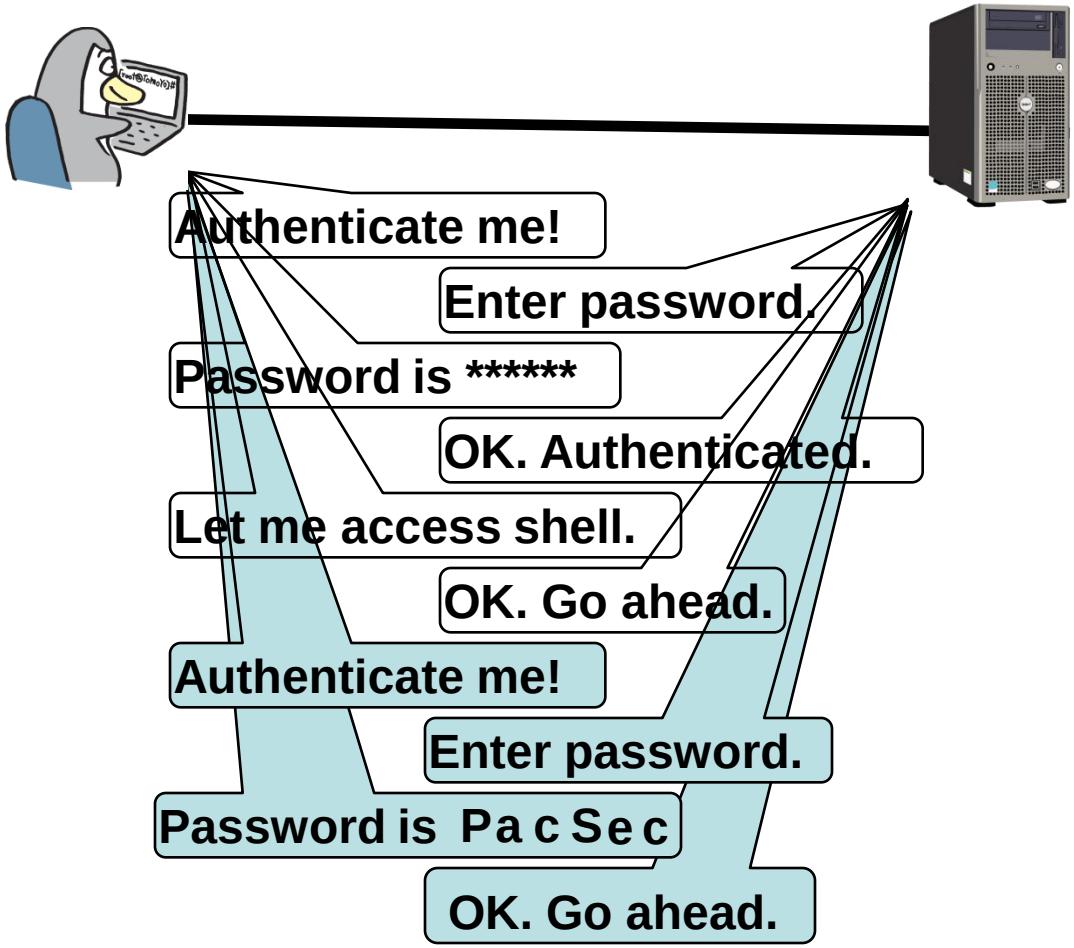


Case 1: Interactive shell session

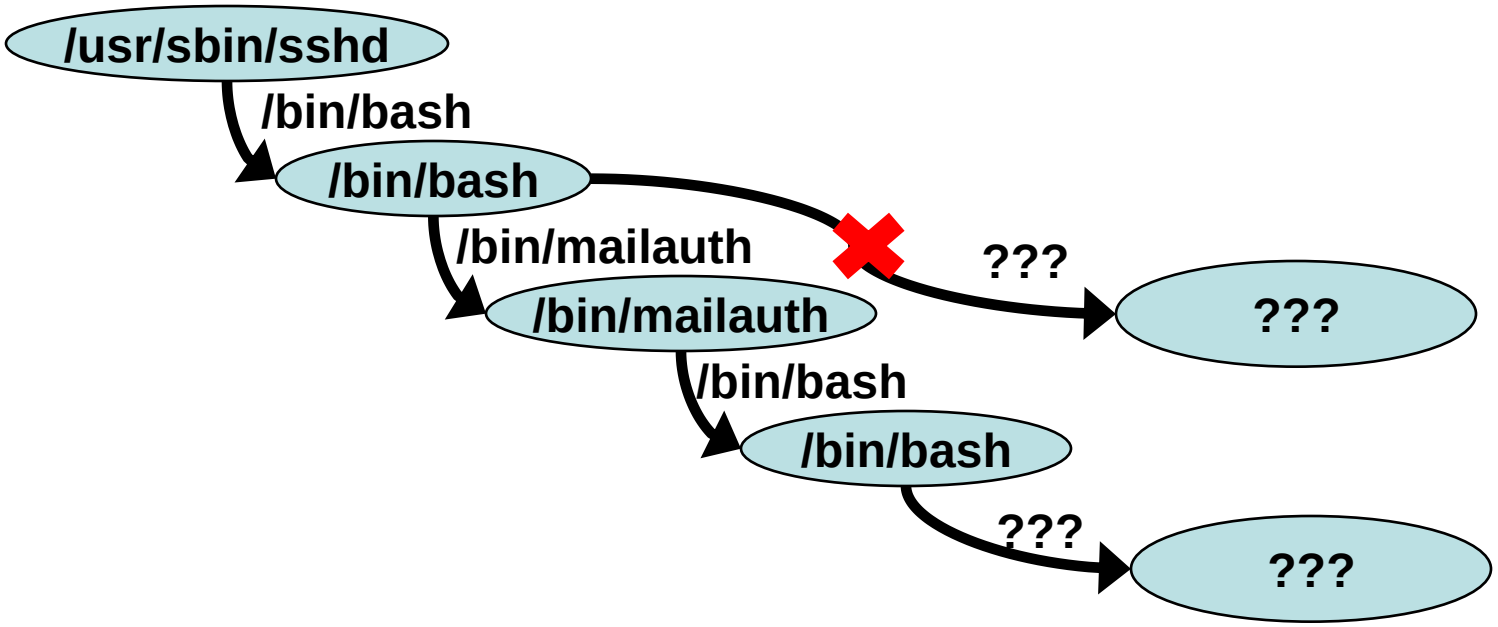
- Advantages
  - No limitations for available factors.
    - No need to follow standards like RFC.
    - No need to disclose factors you use.
  - Unimaginable authentic method.
    - You can use methods an intruder never expects.
    - Even shorter password, brute force becomes meaningless by combining password and typing timing information.

Case 1: Interactive shell session

- Disadvantages
  - You need "Operating Systems with Advanced Access Control Features".
    - To restrict commands executed from login shell.
    - Namely MAC (Mandatory Access Control).
  - Difficult to use if Round Trip Time is large.
    - It might be convenient for defending the system against foreign incursions or aggression?

Case 2: Interactive shell session

- Utilize one-time password (OTP) and mail.
  - What we need
    - SMTP server
    - own program /bin/mailauth



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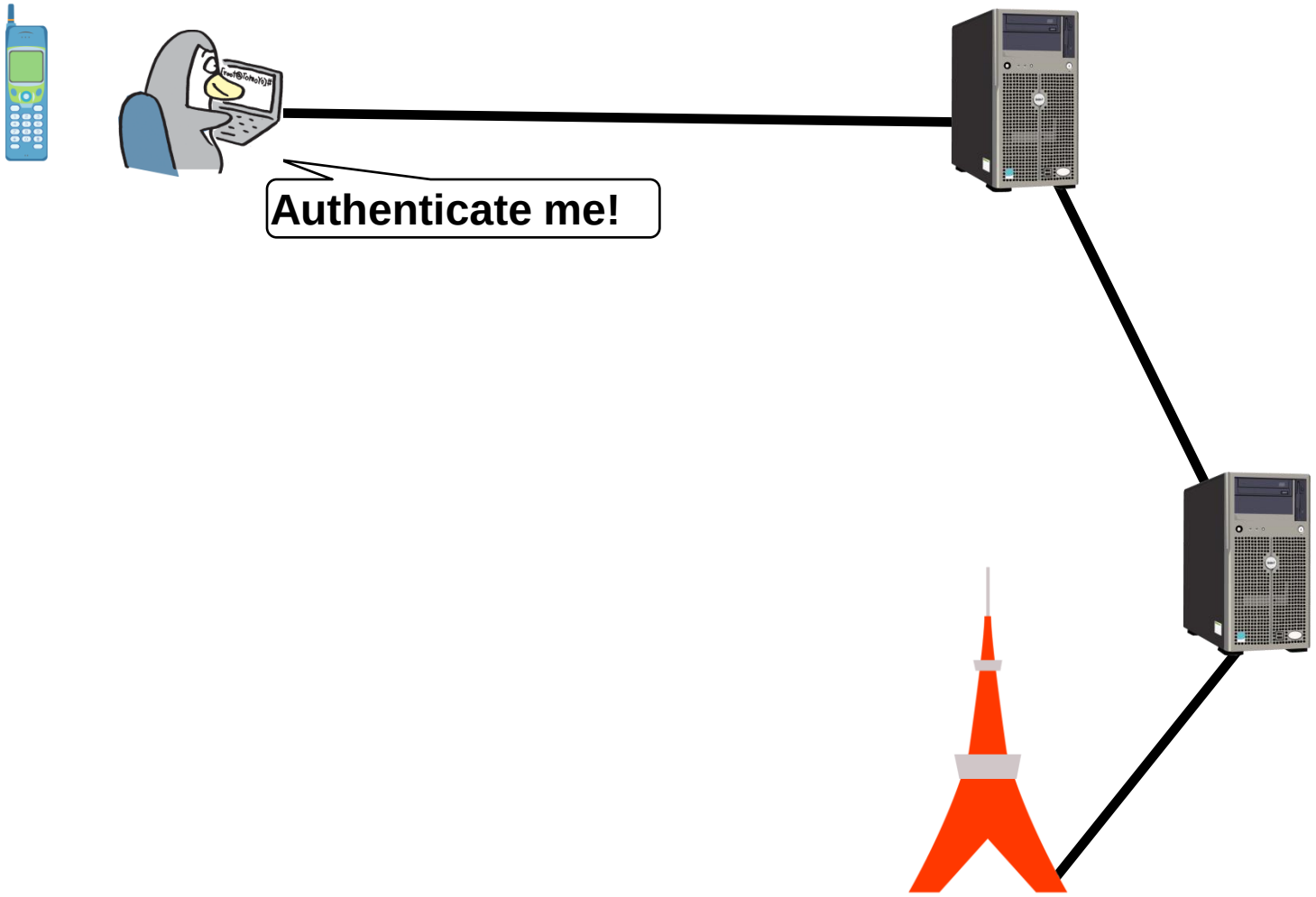

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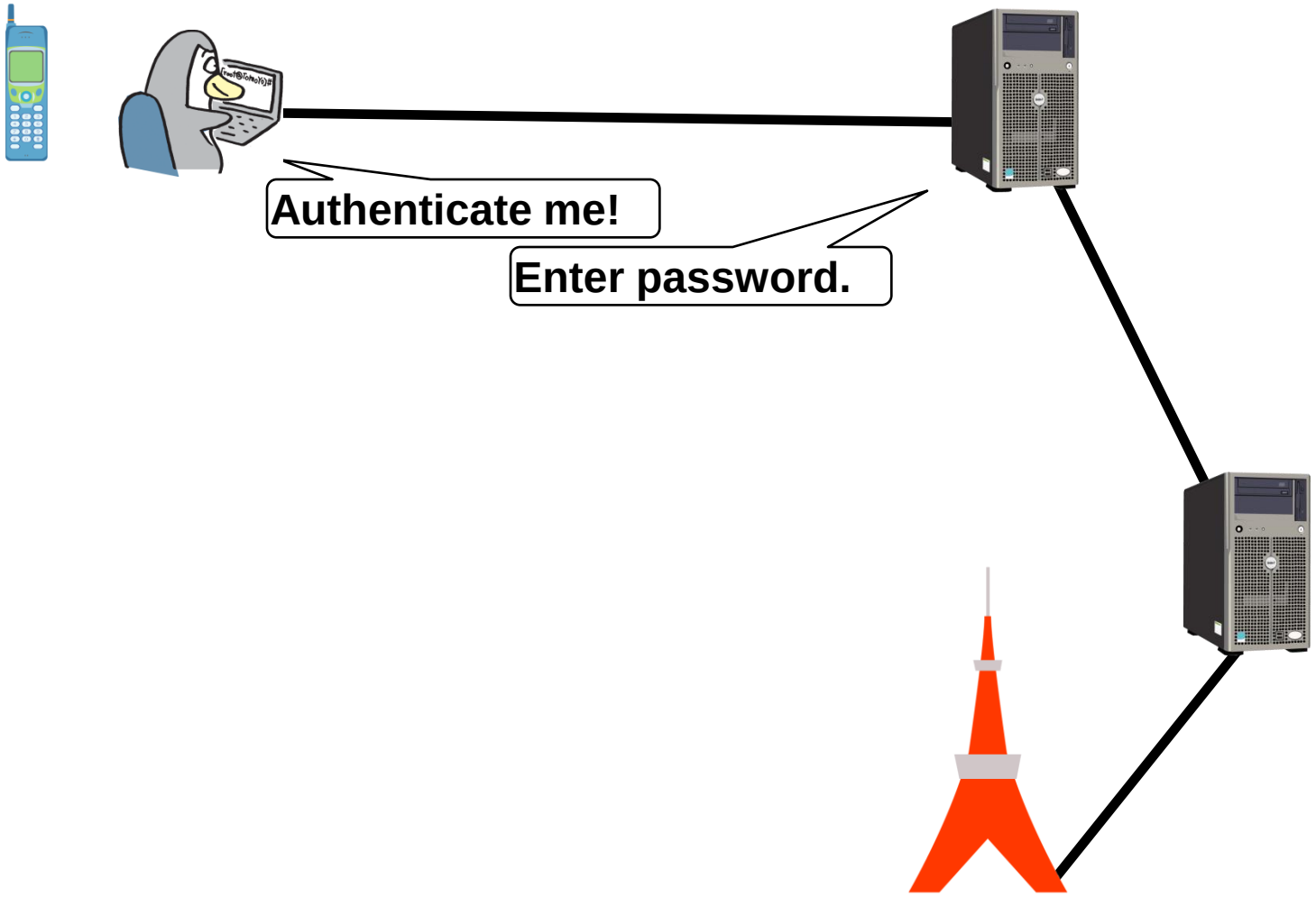

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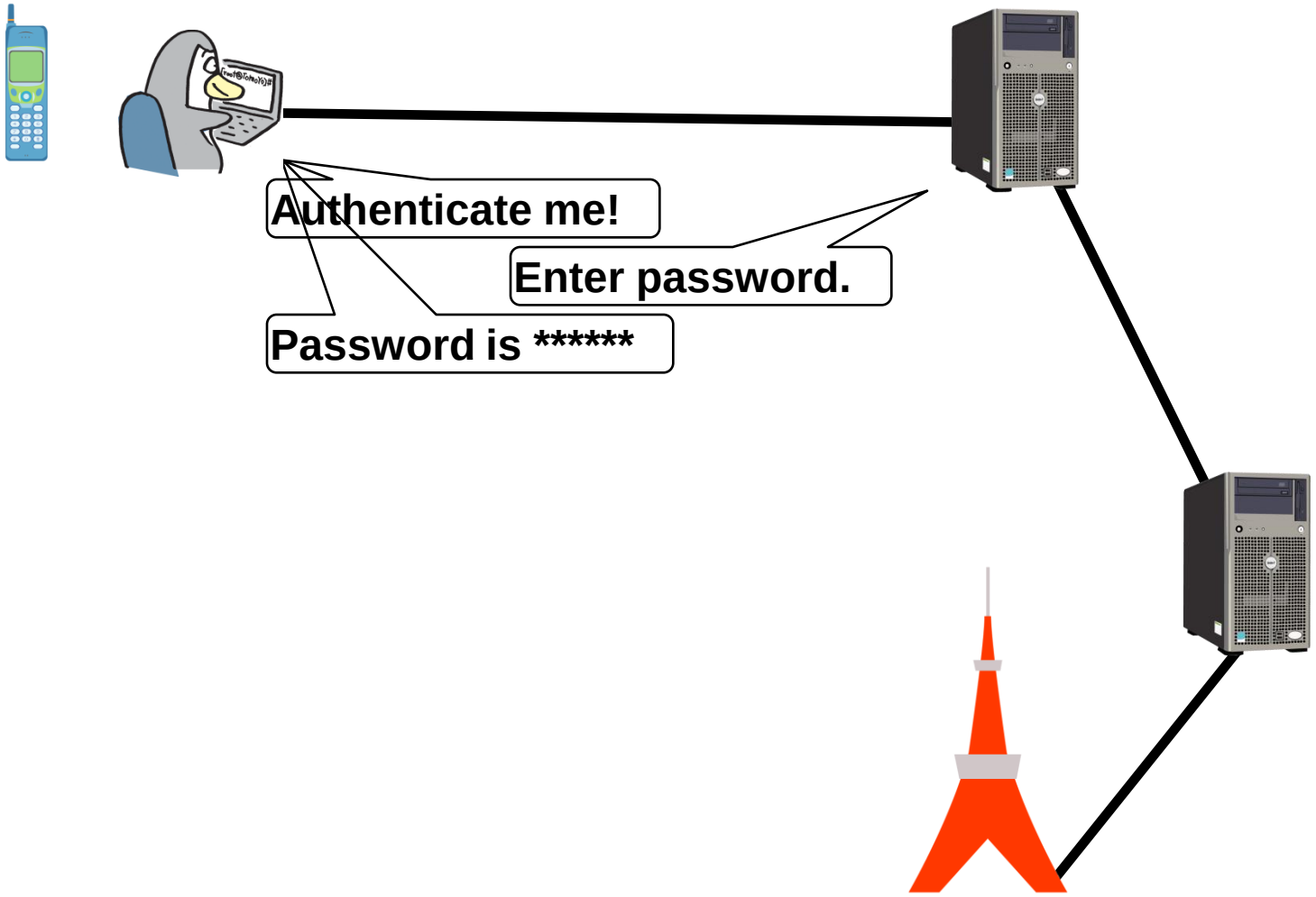

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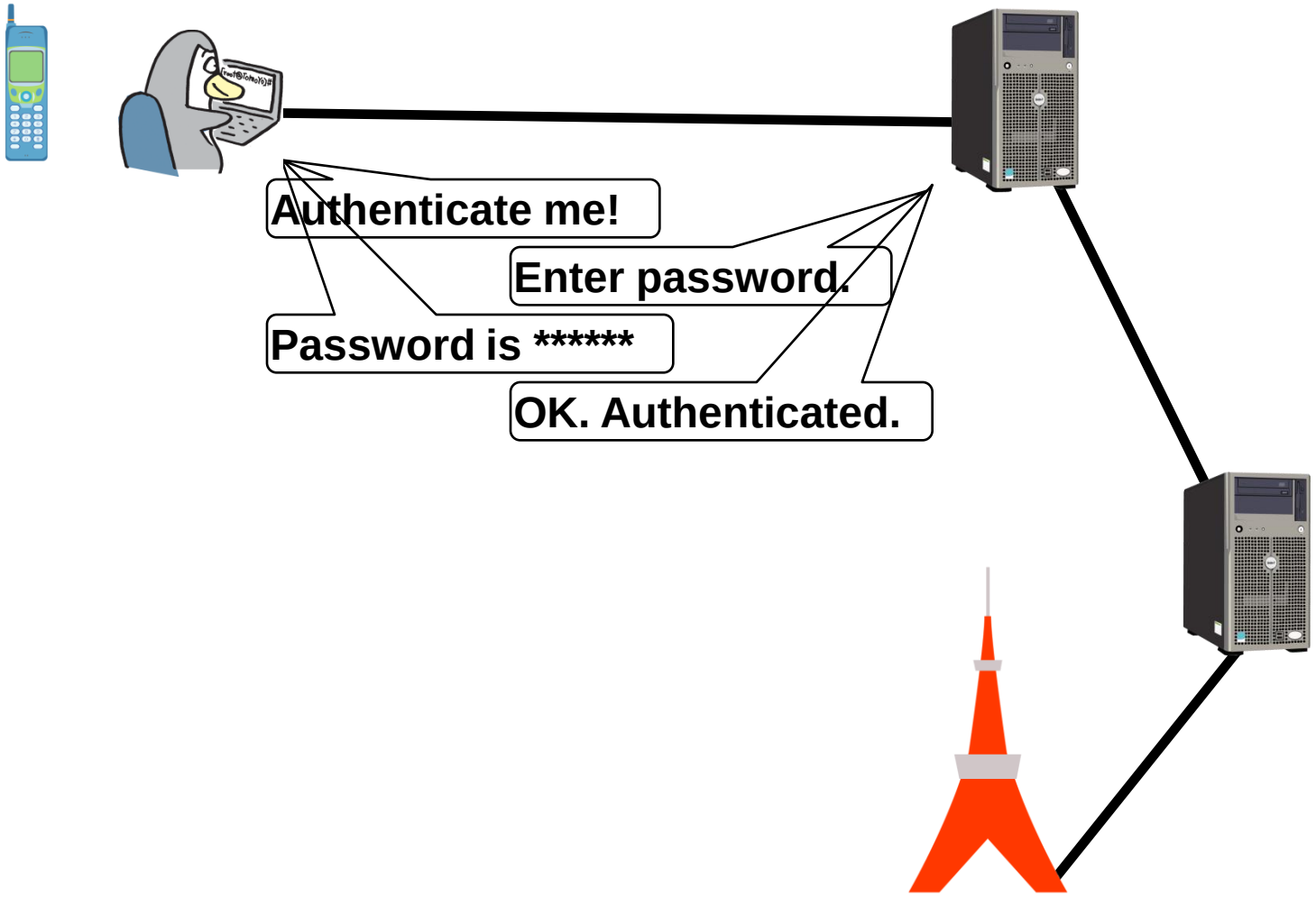

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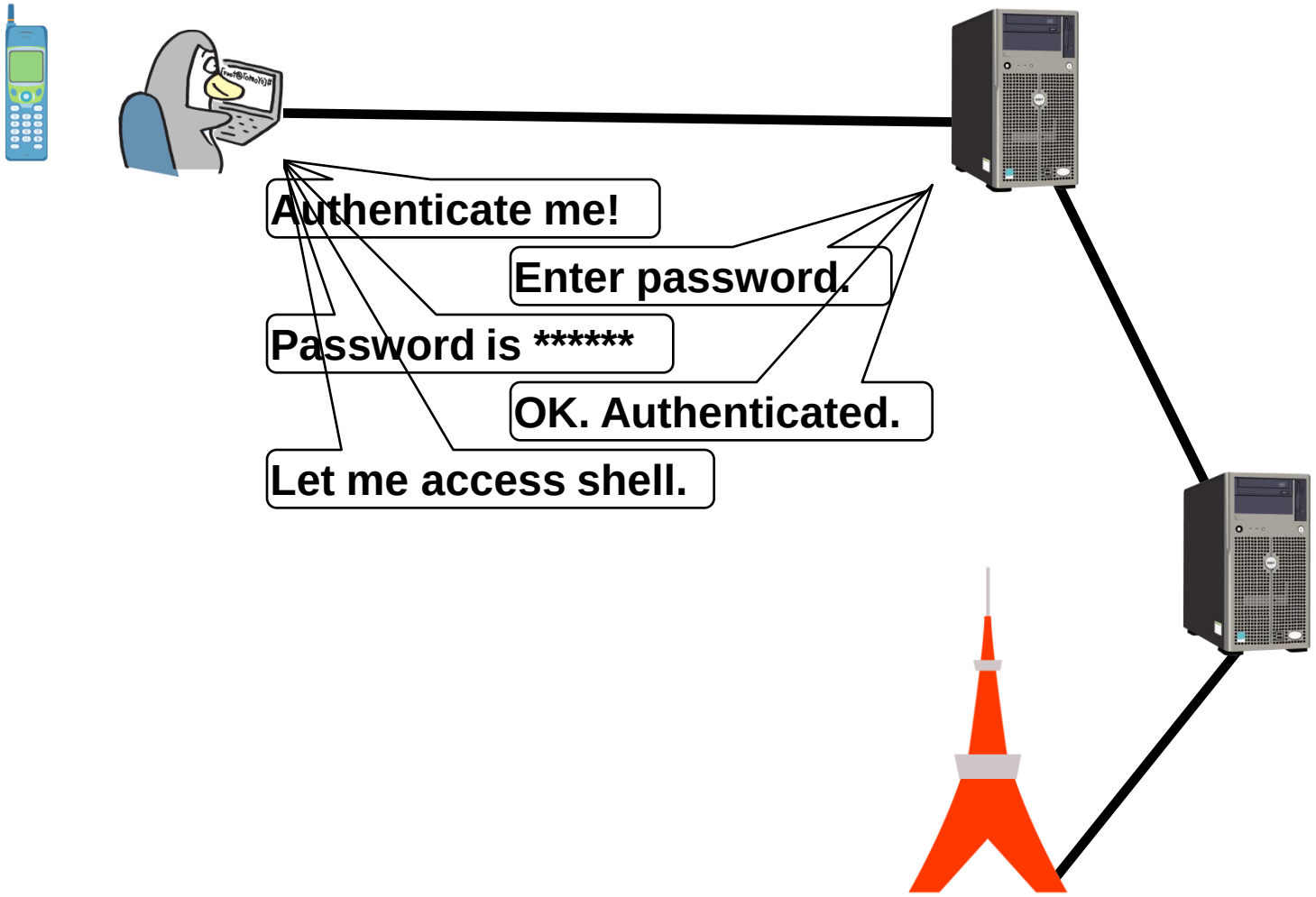

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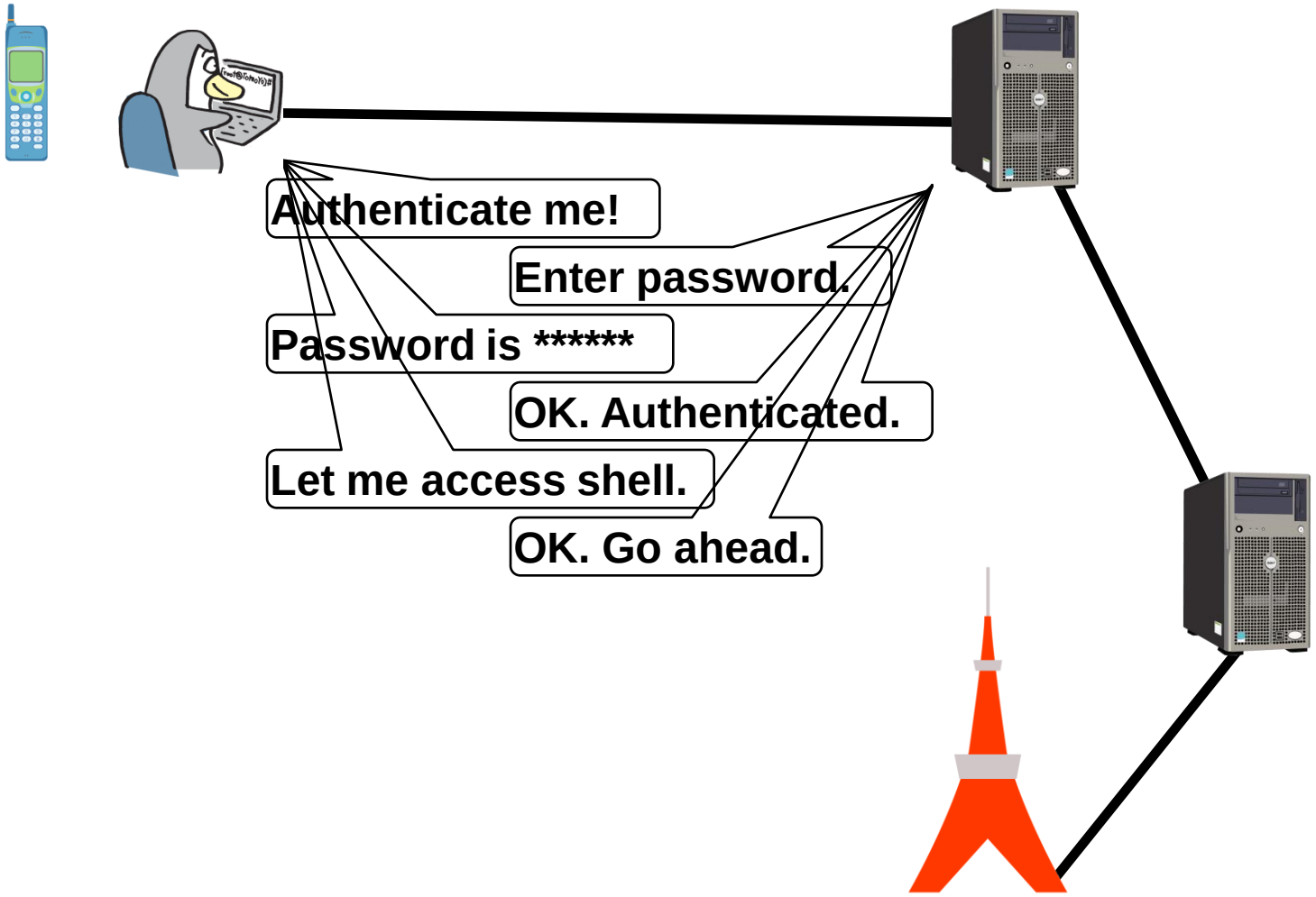

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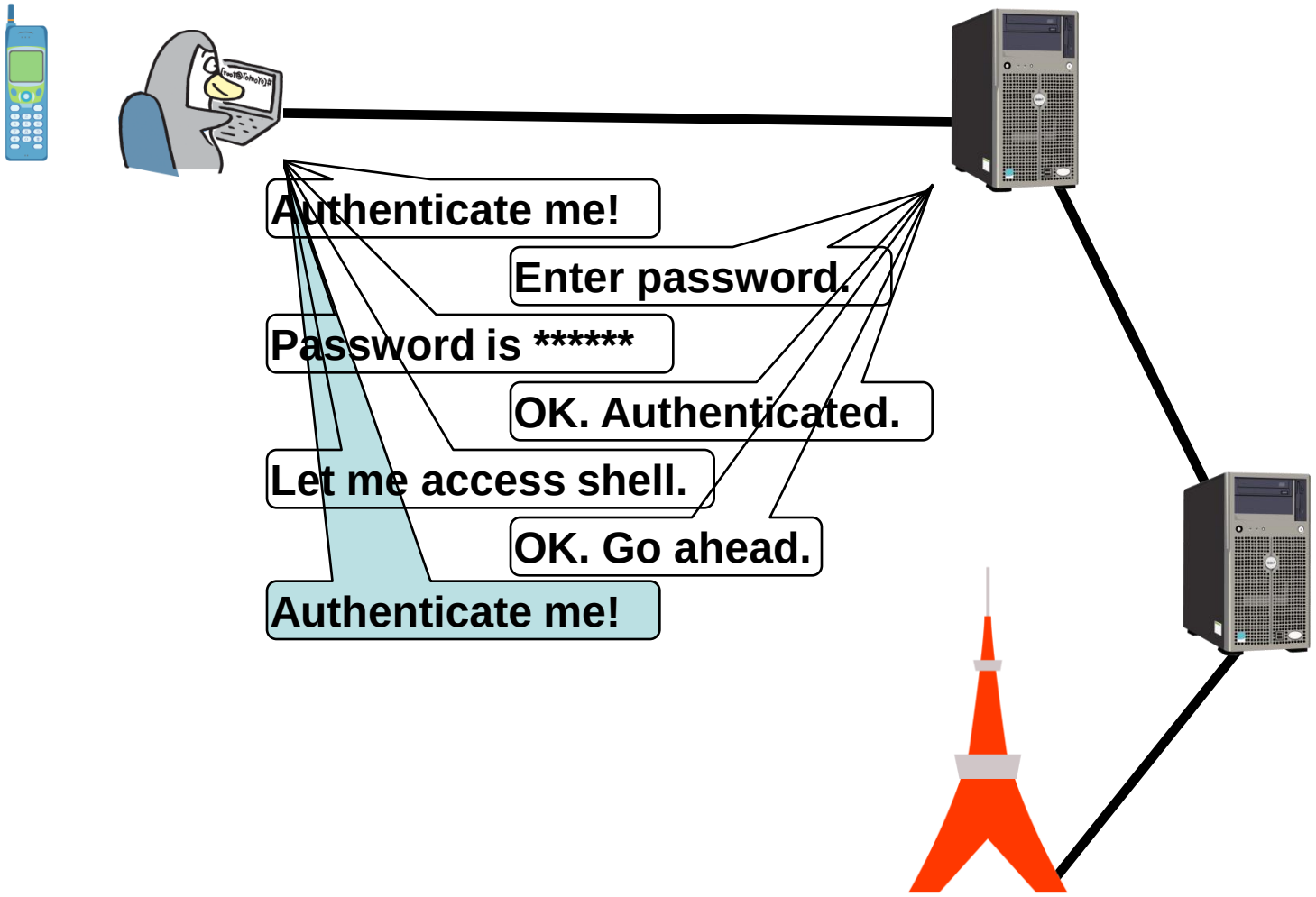

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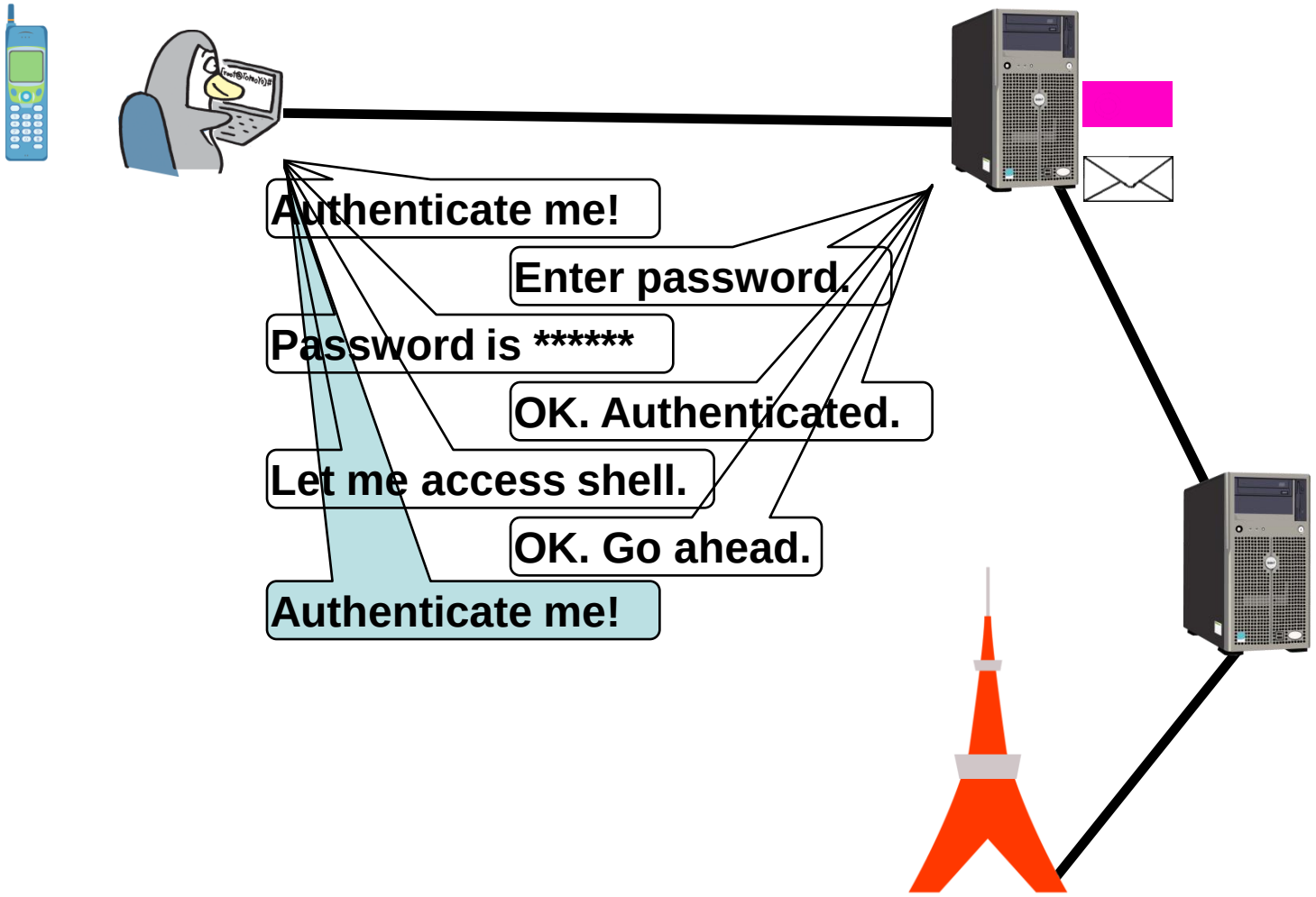

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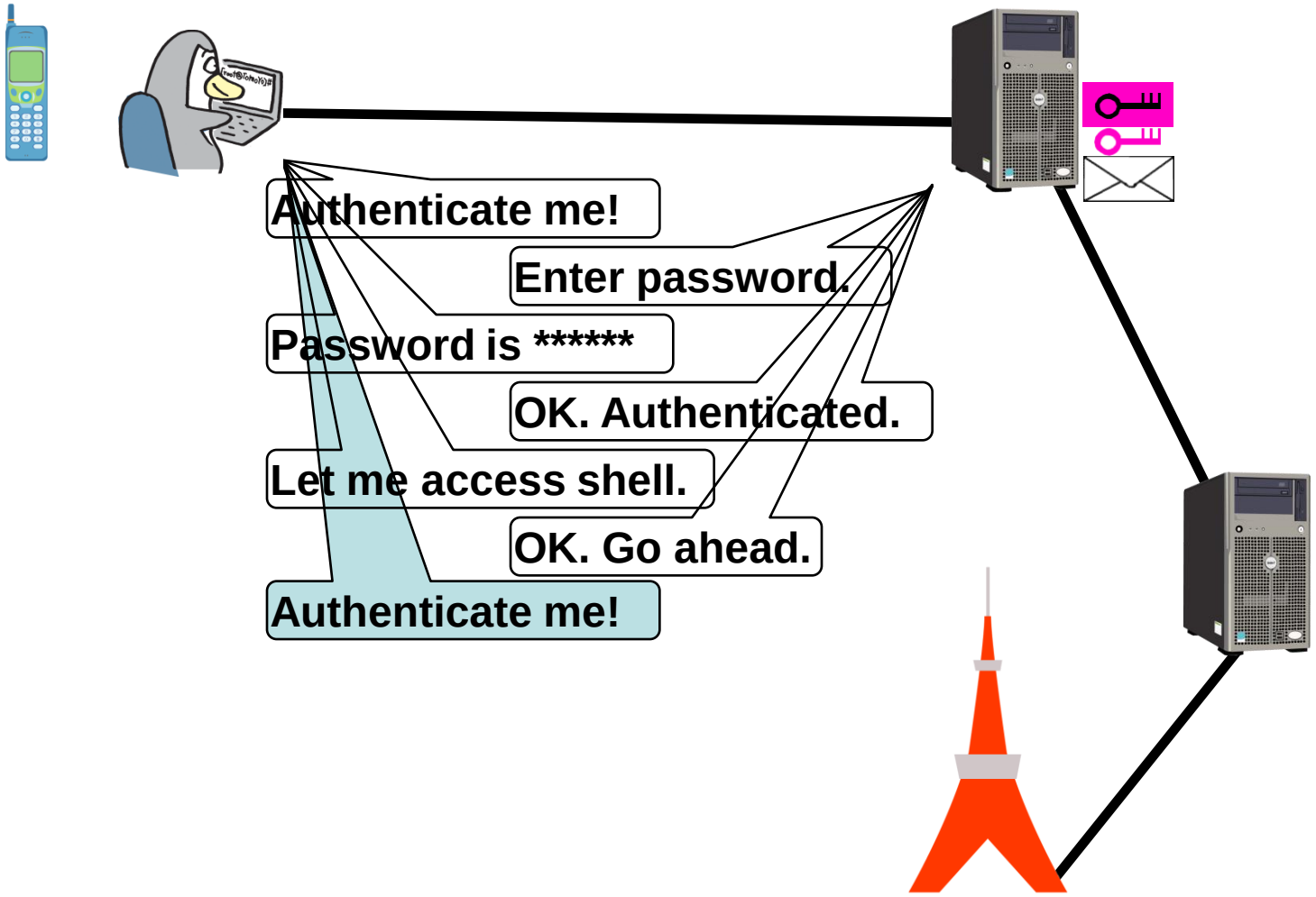

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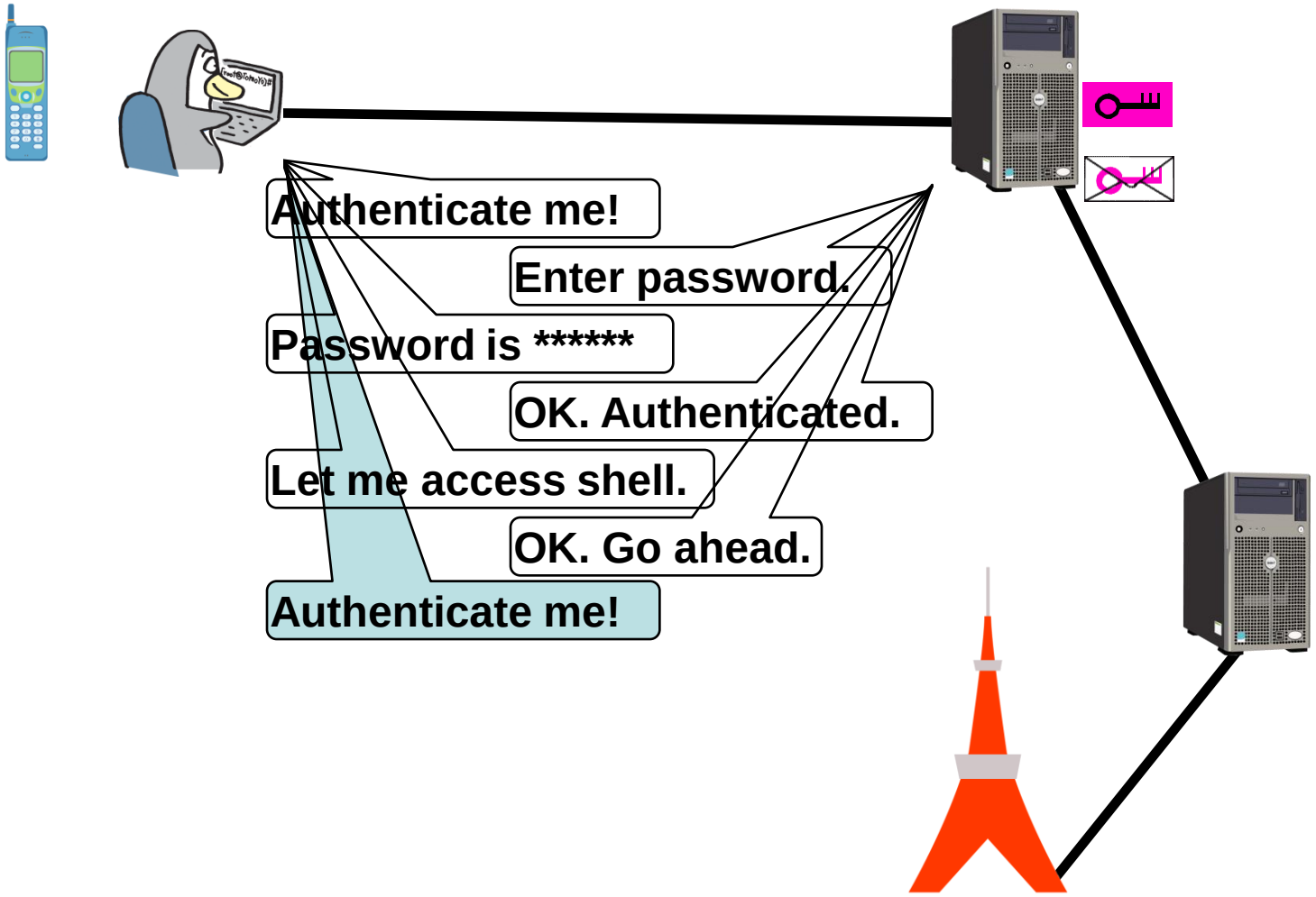

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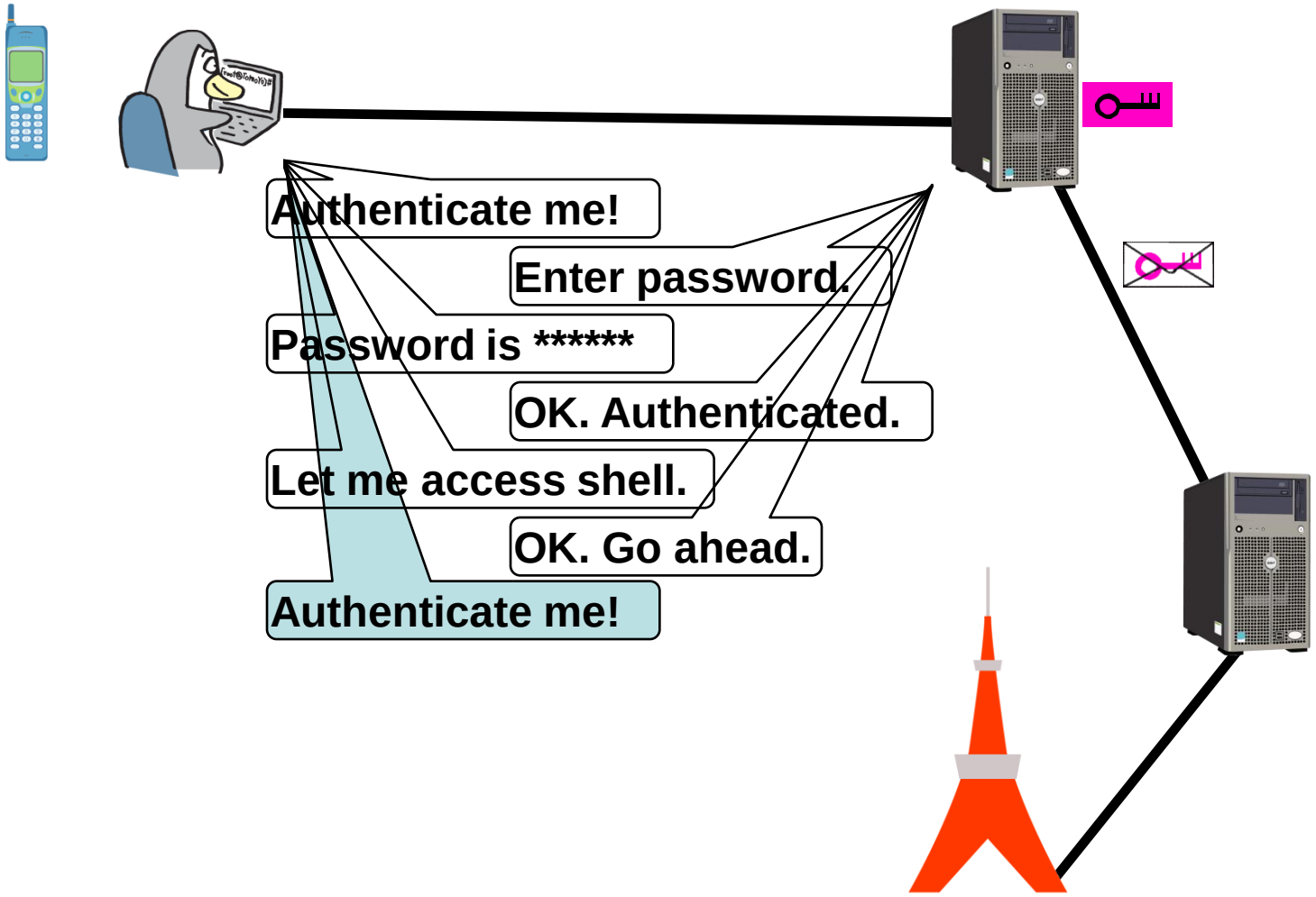

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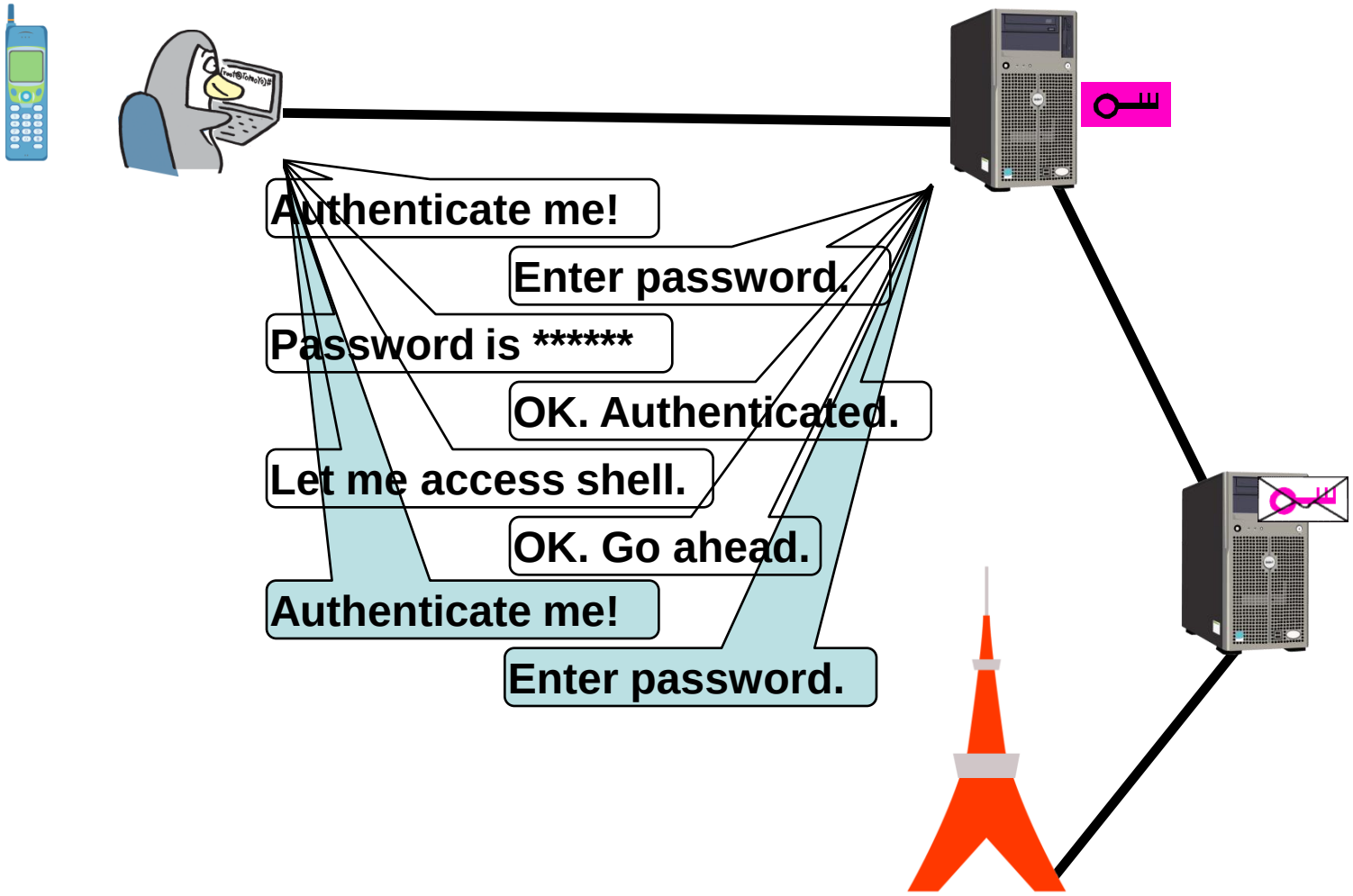

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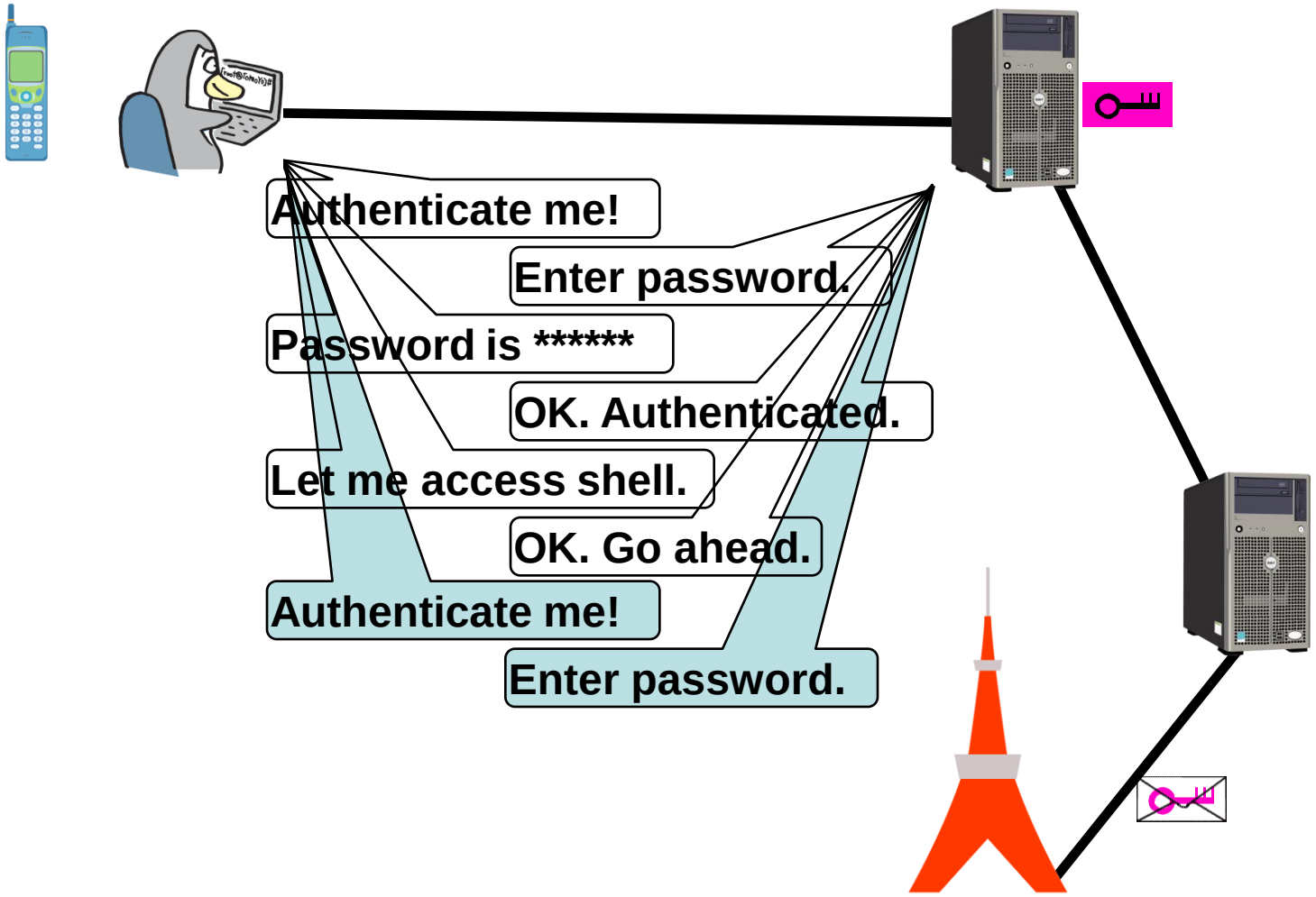

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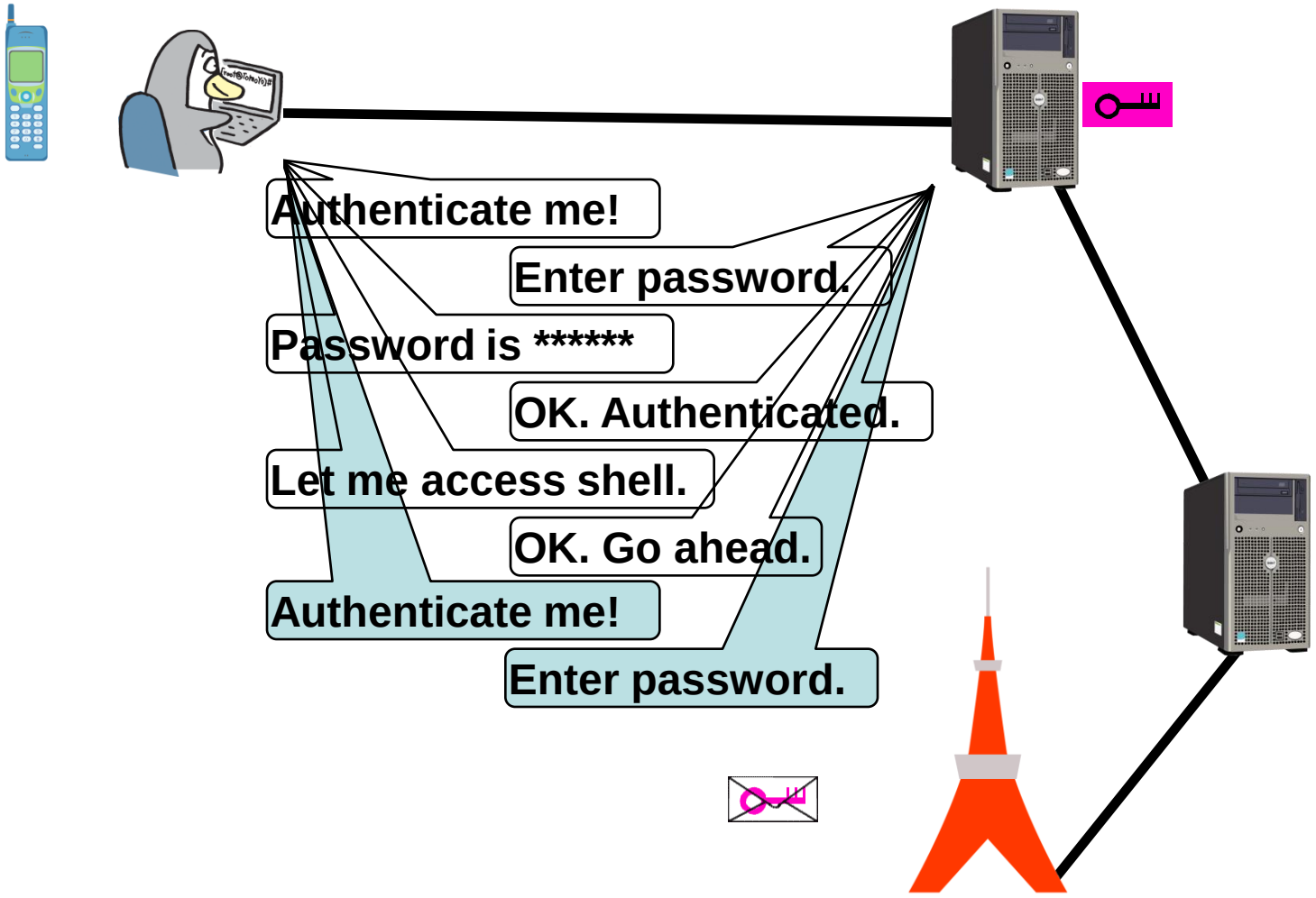

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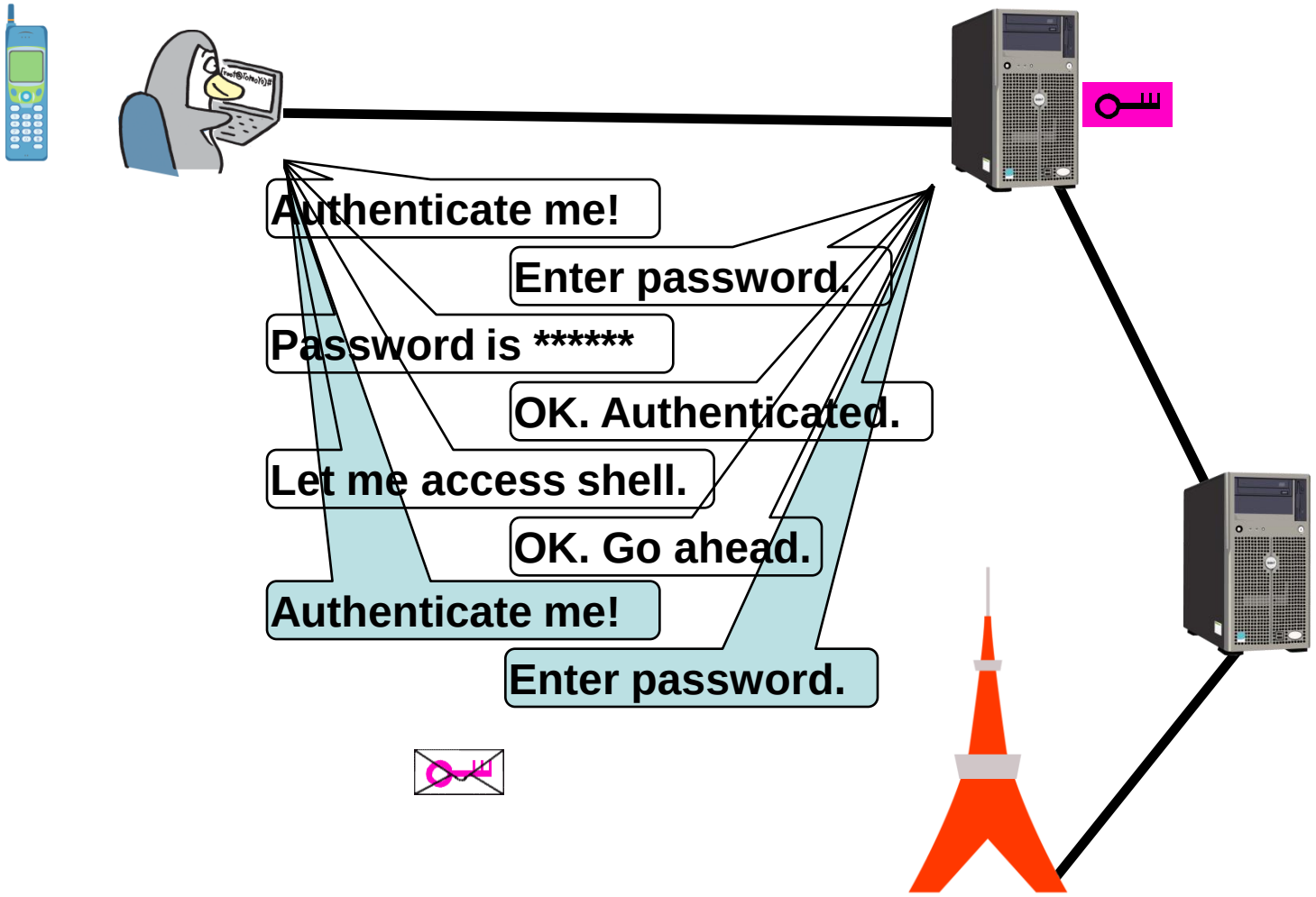

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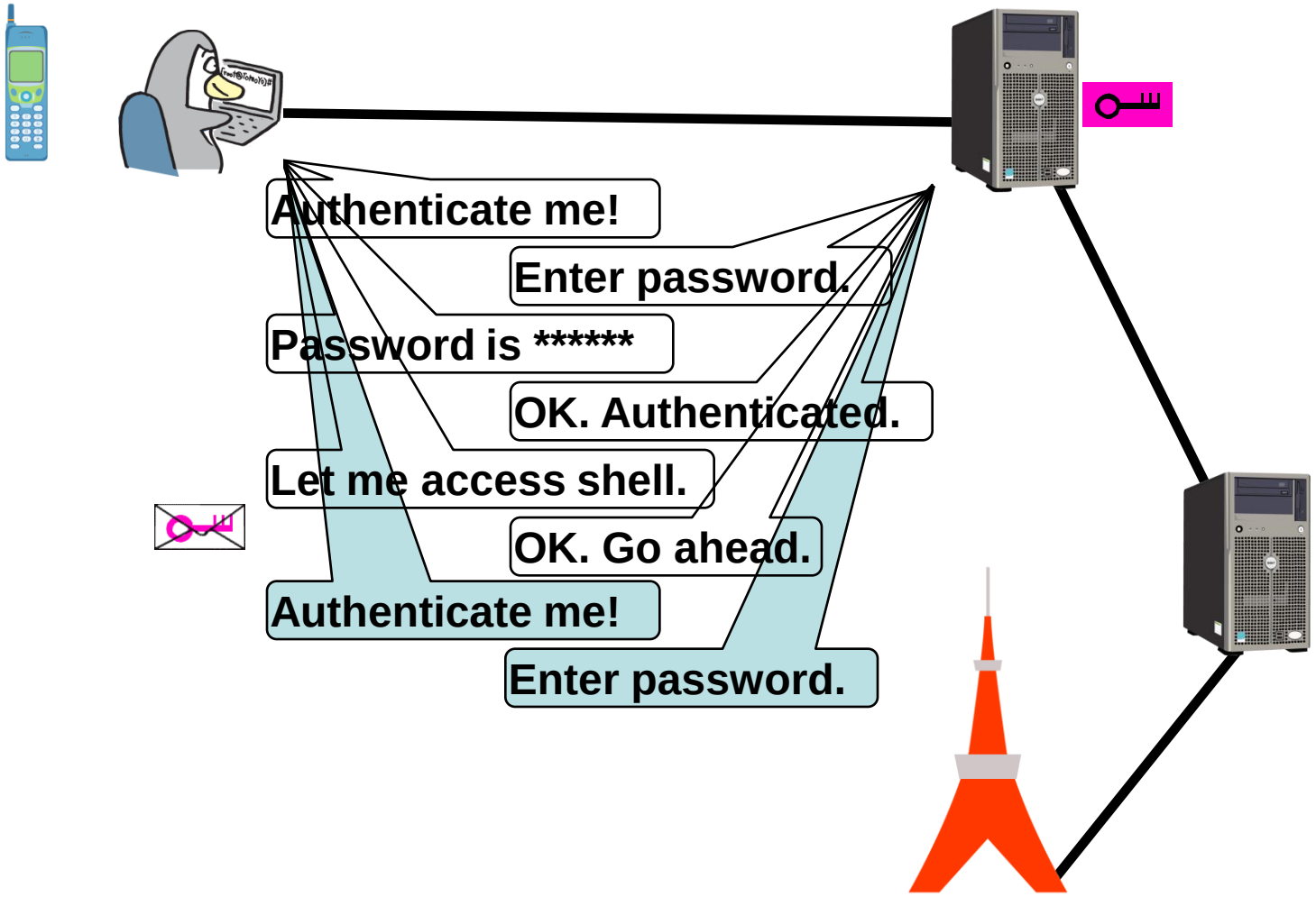

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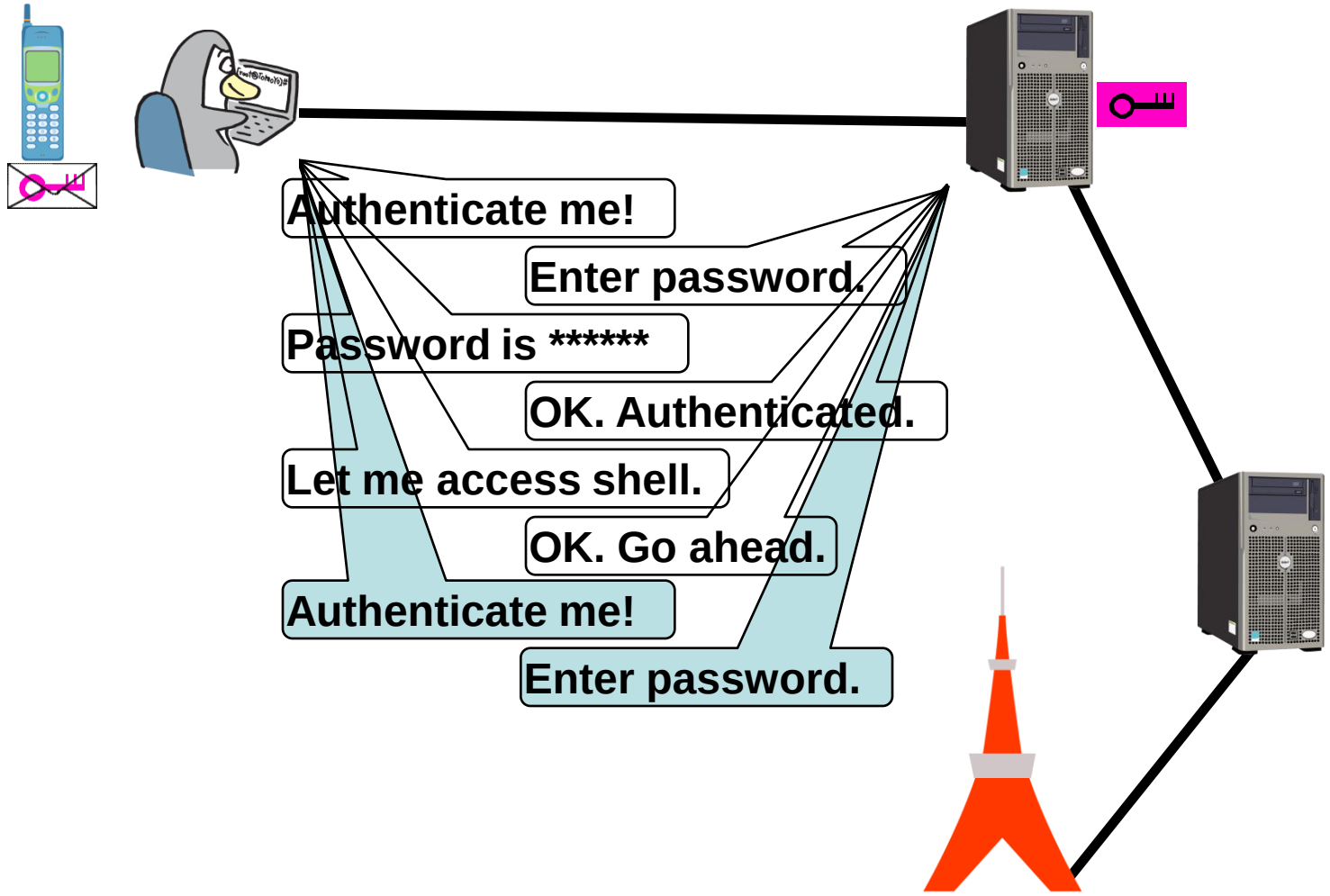

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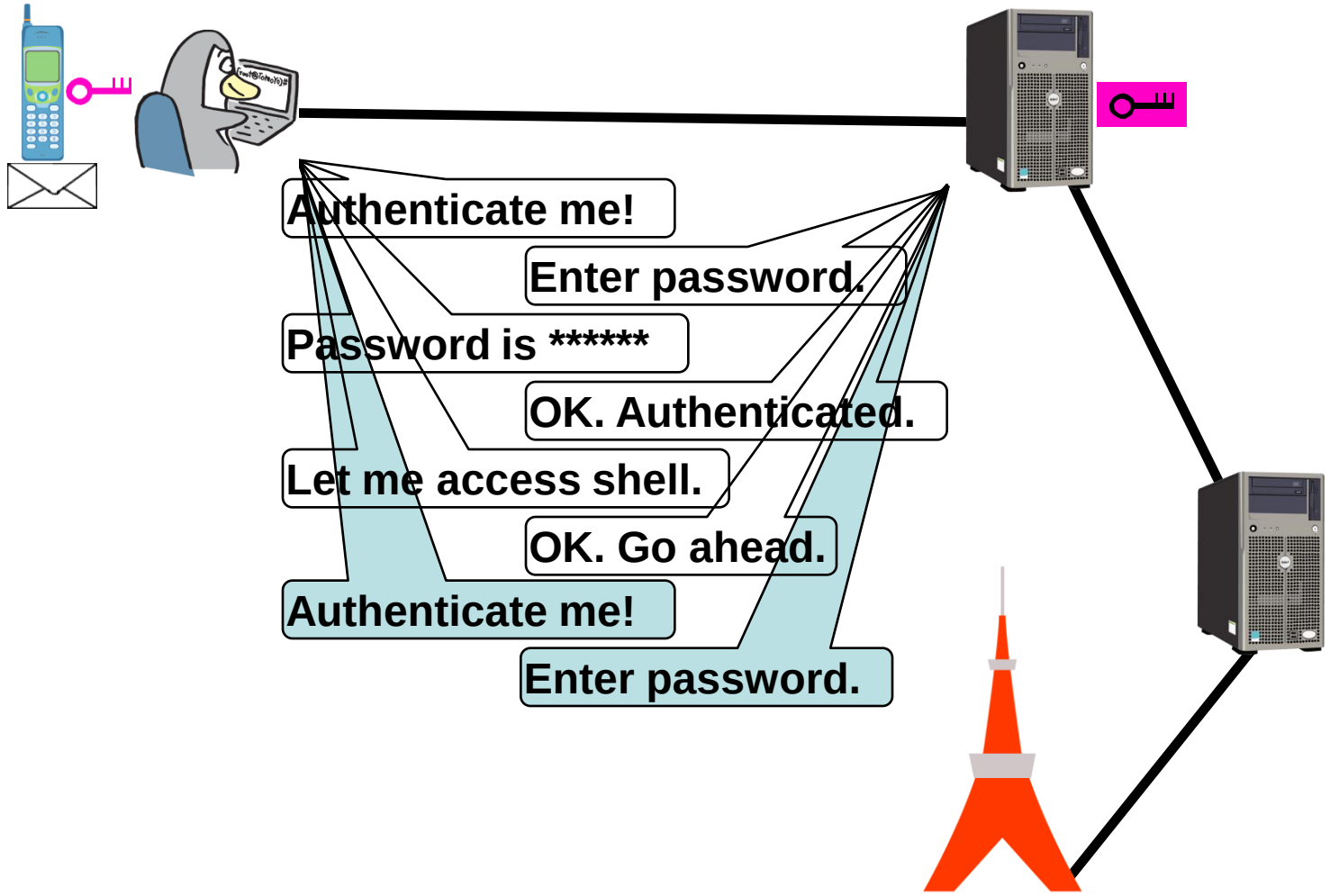

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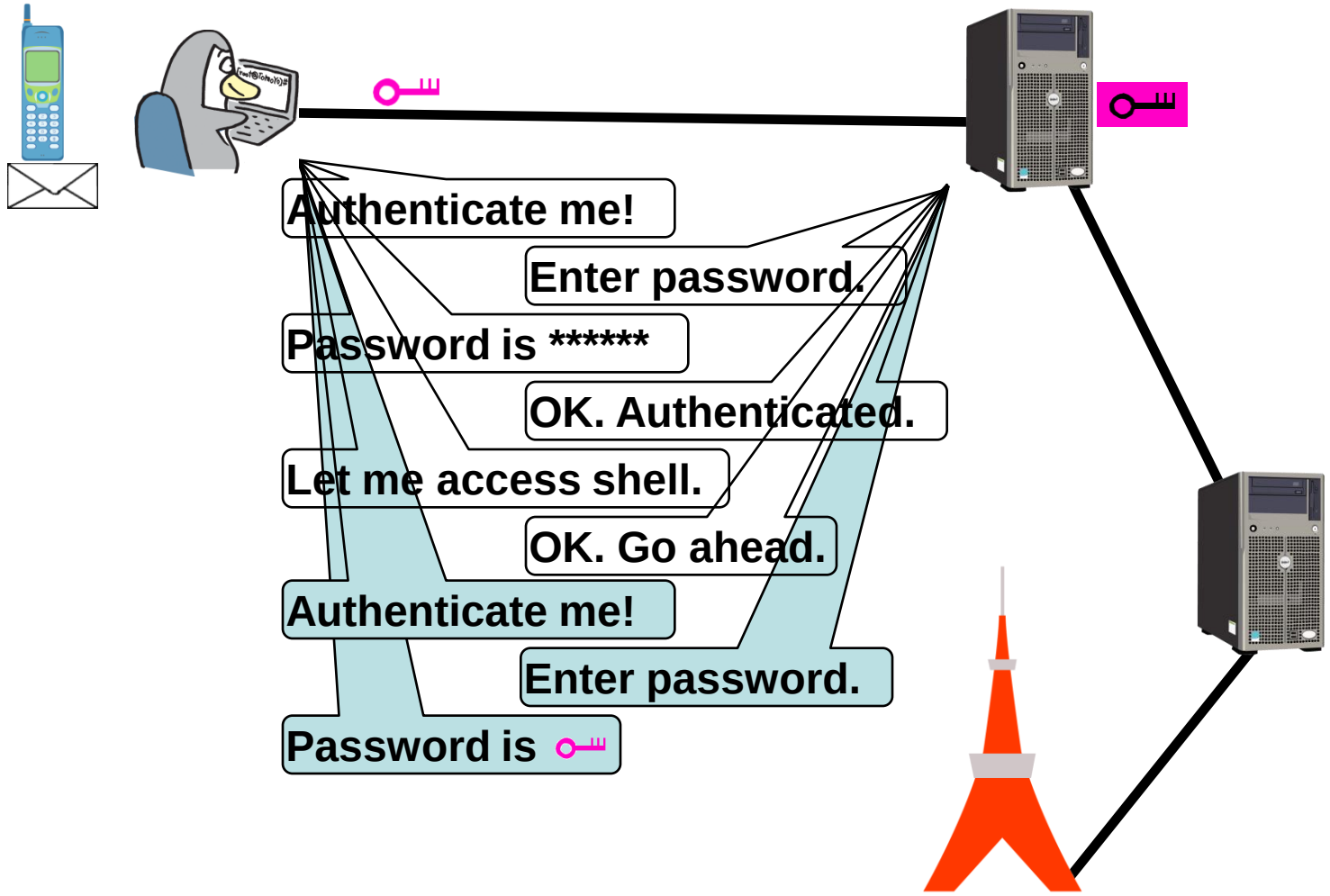

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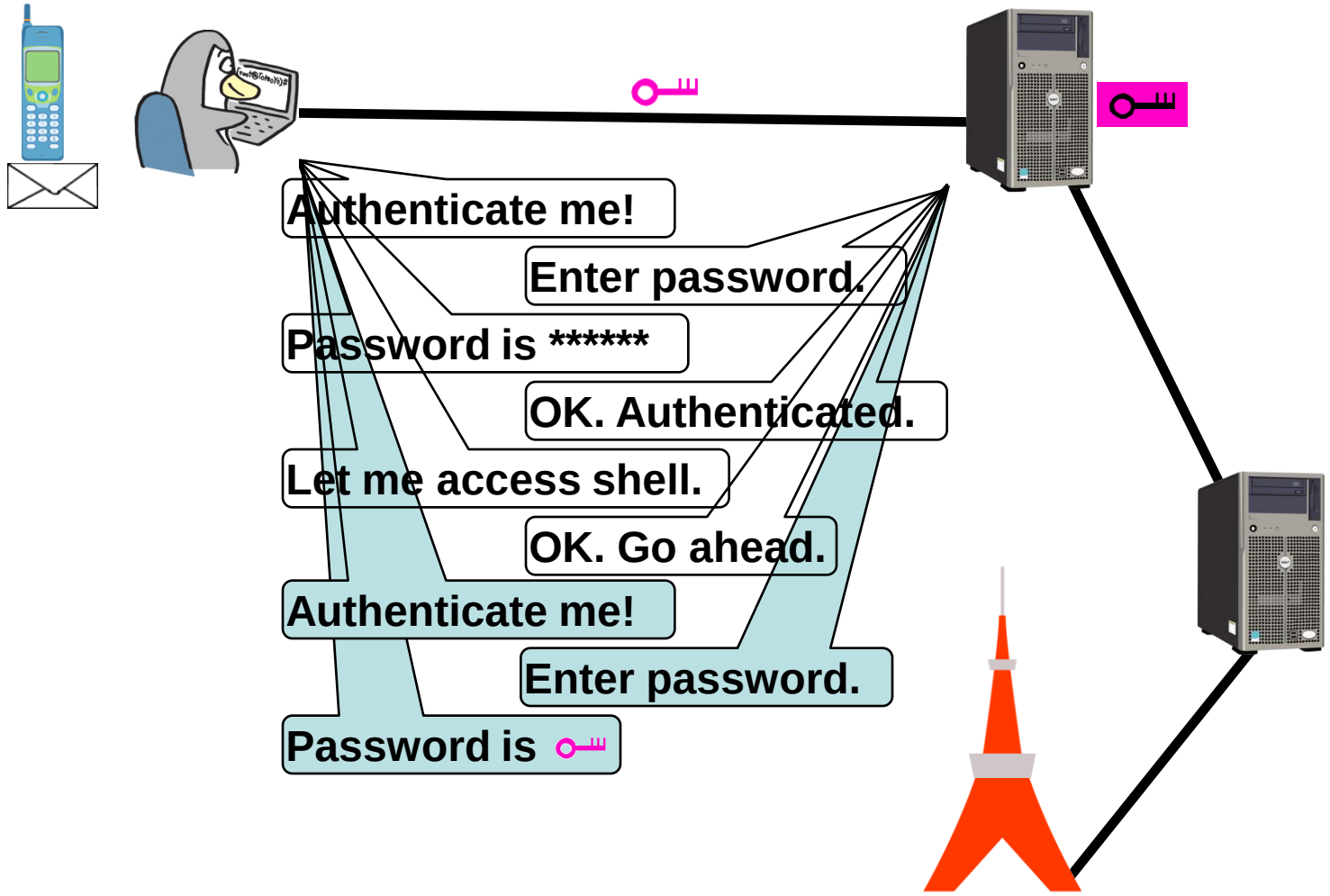

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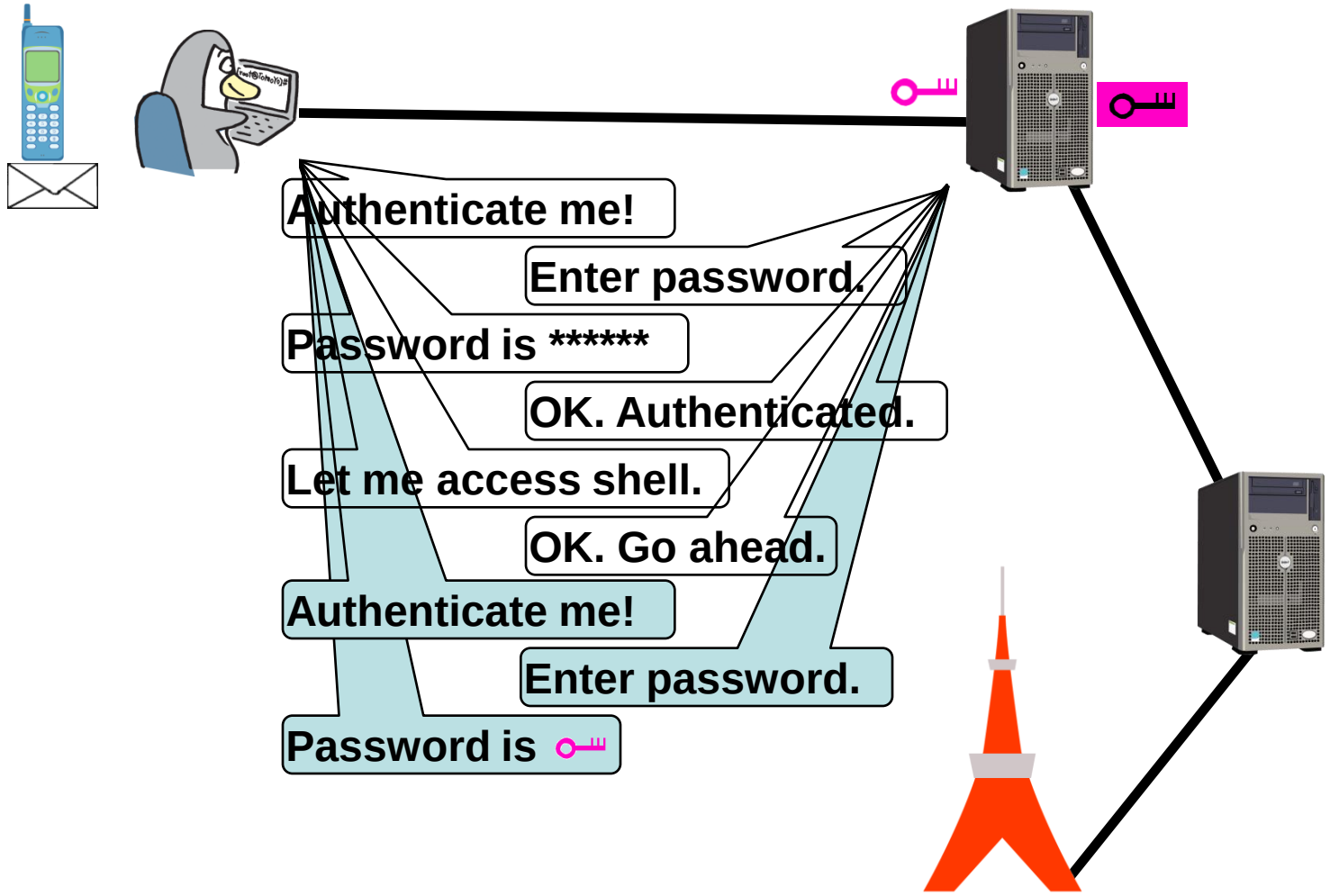

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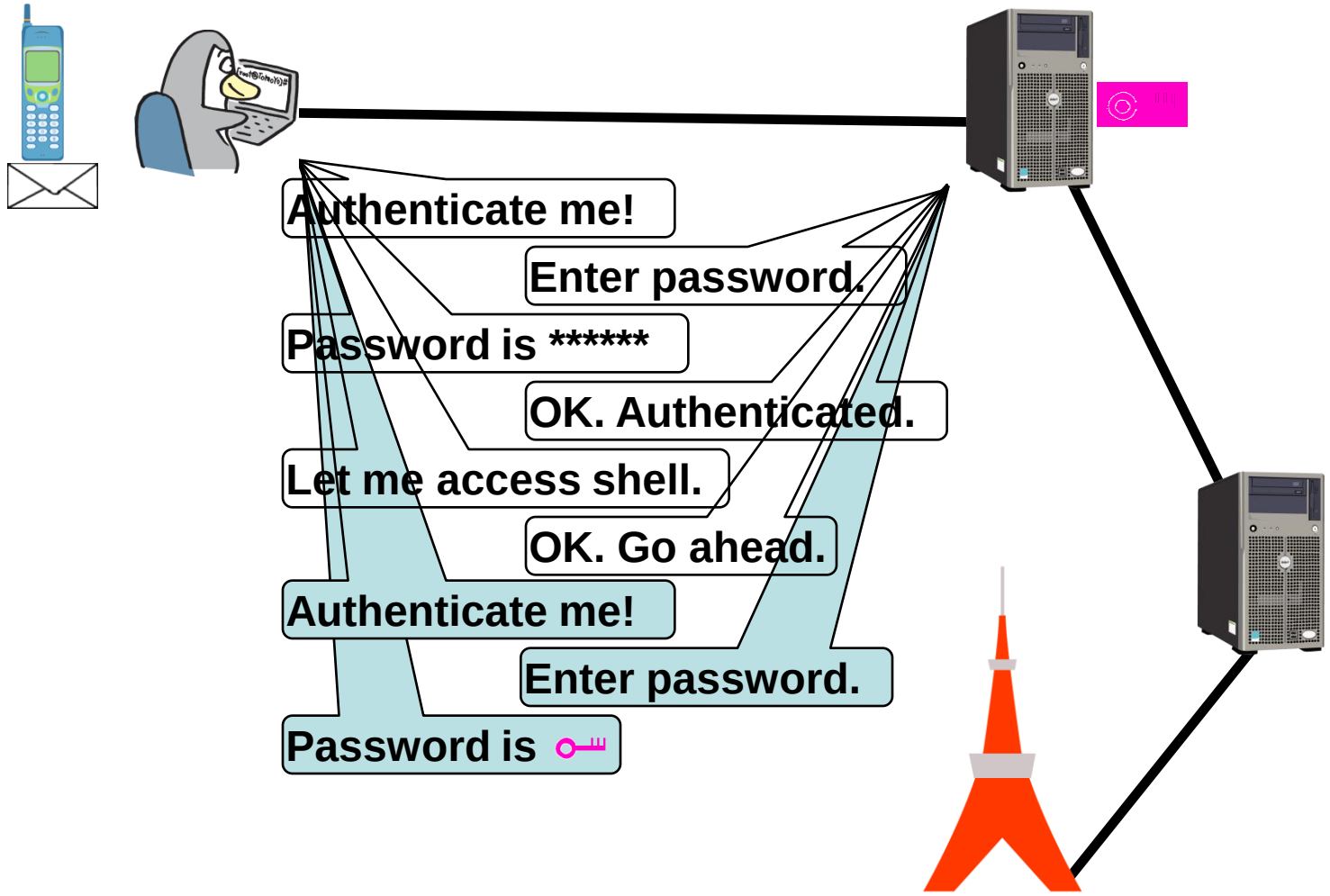

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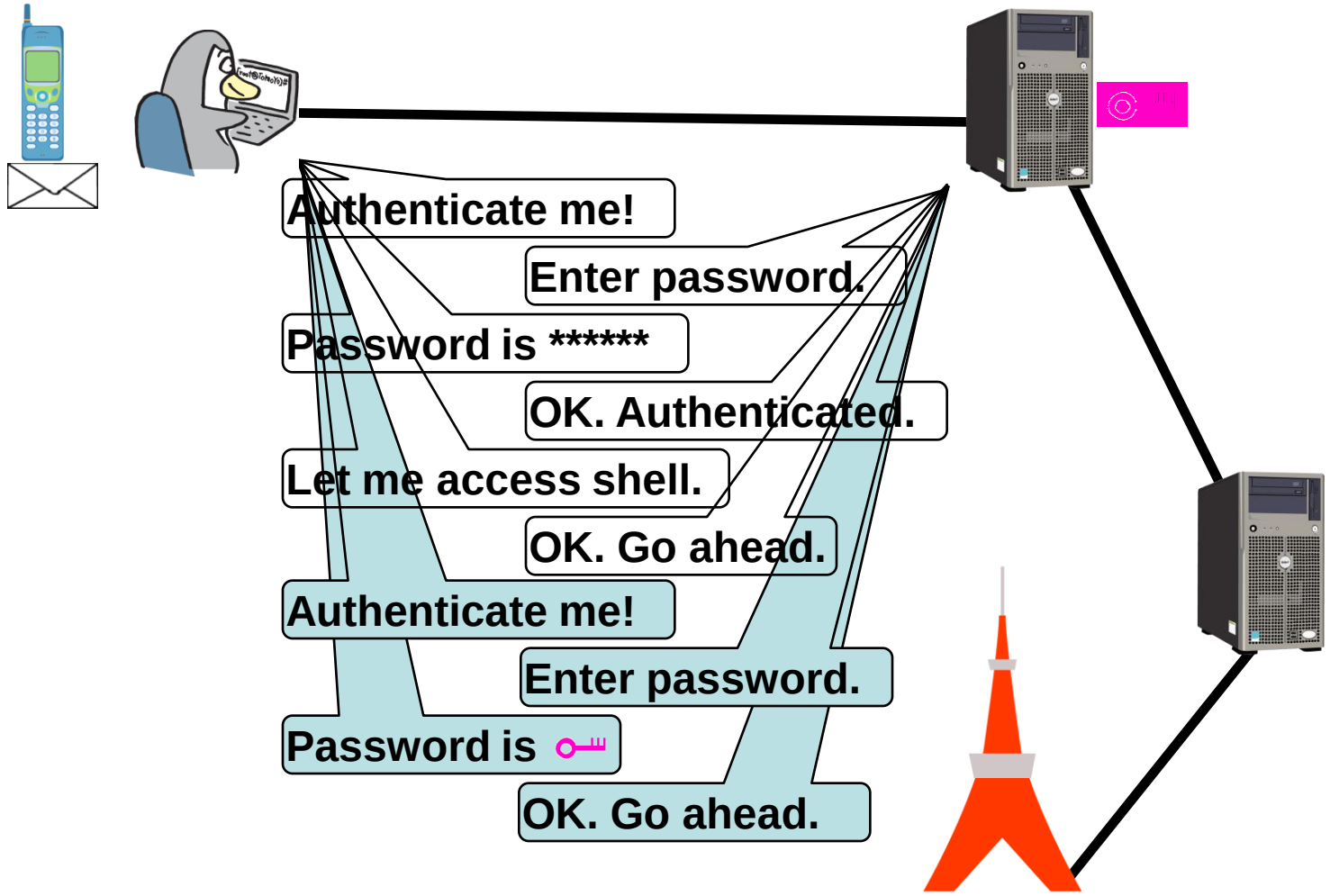

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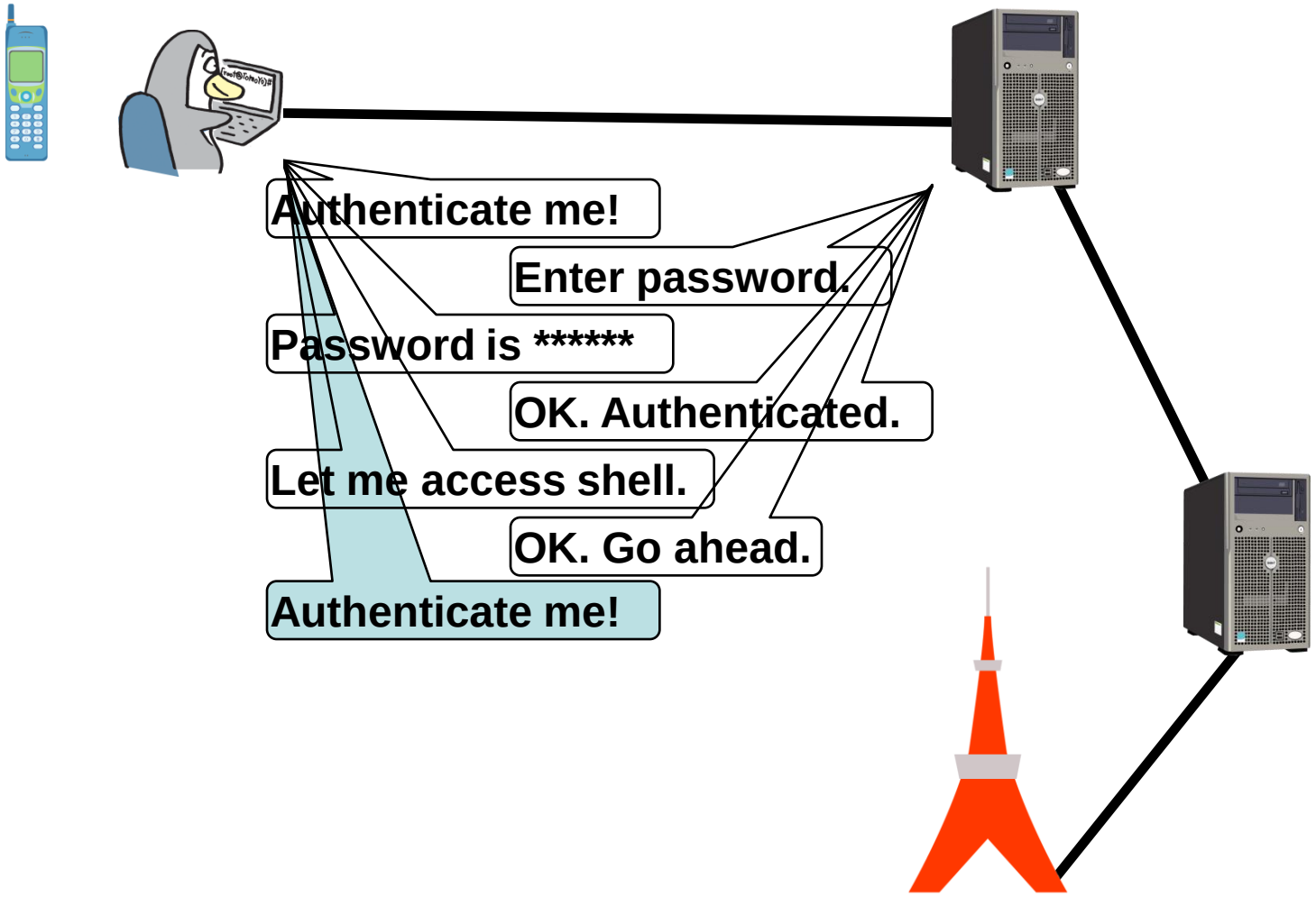
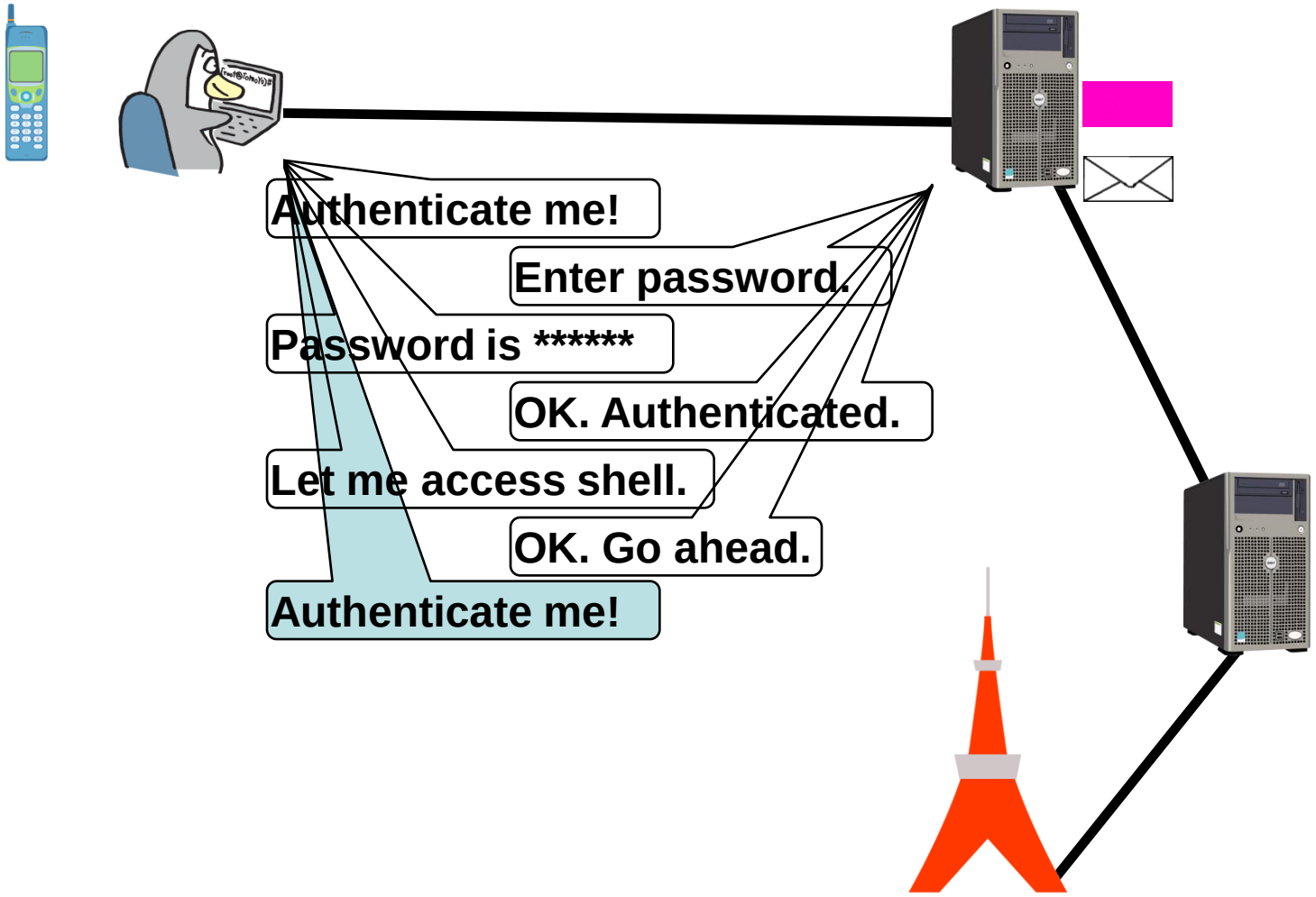


Case 2: Interactive shell session



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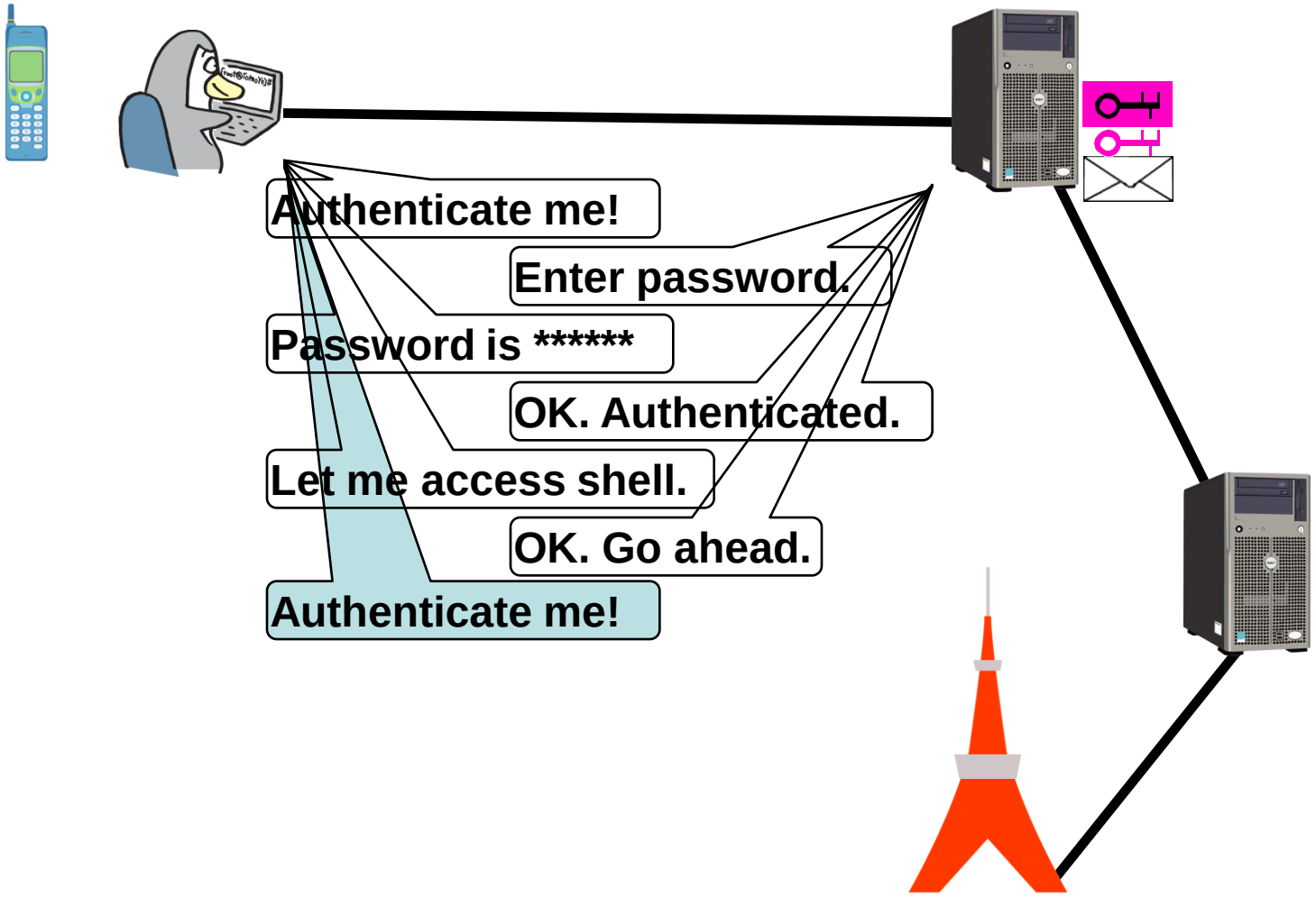

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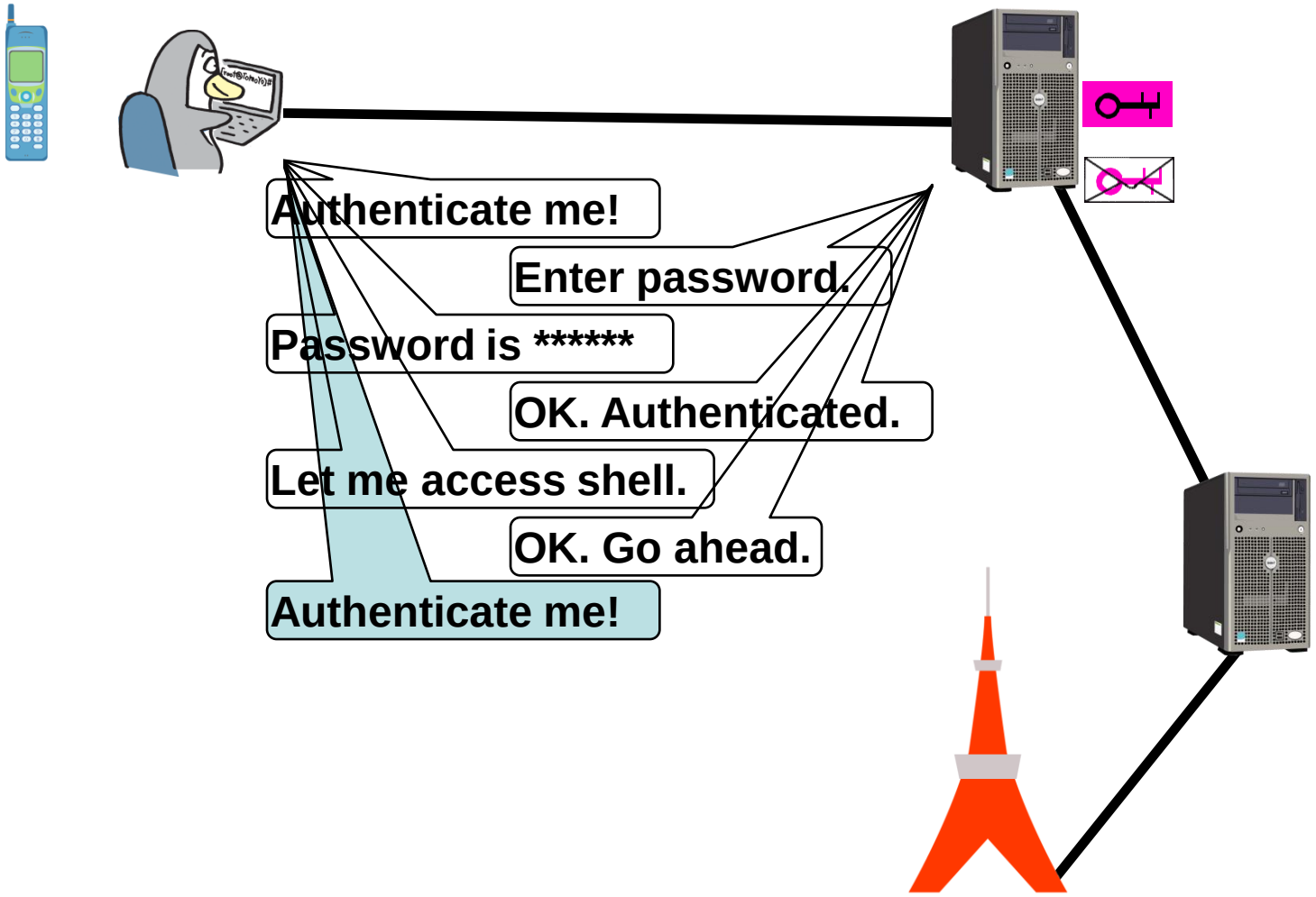

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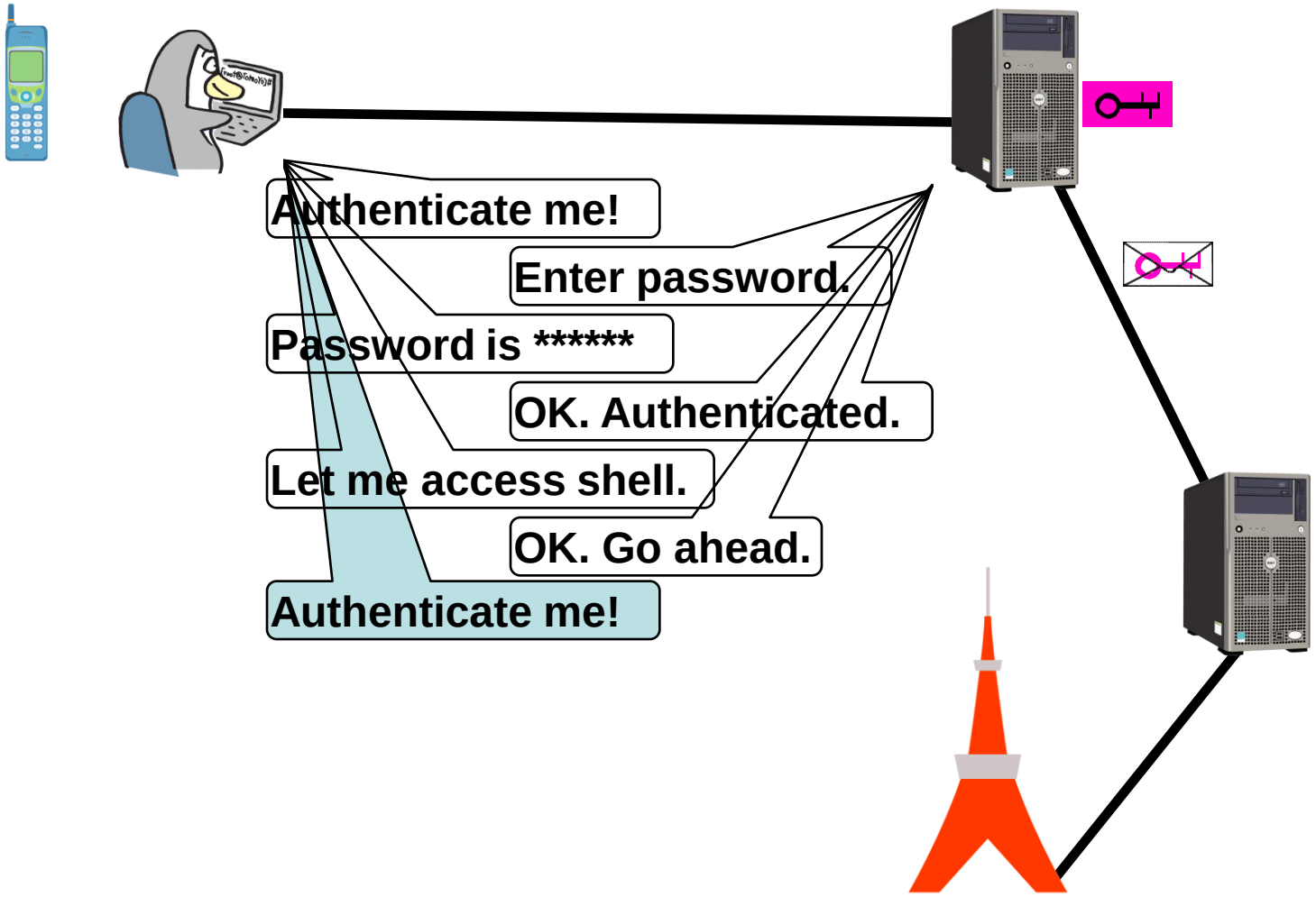

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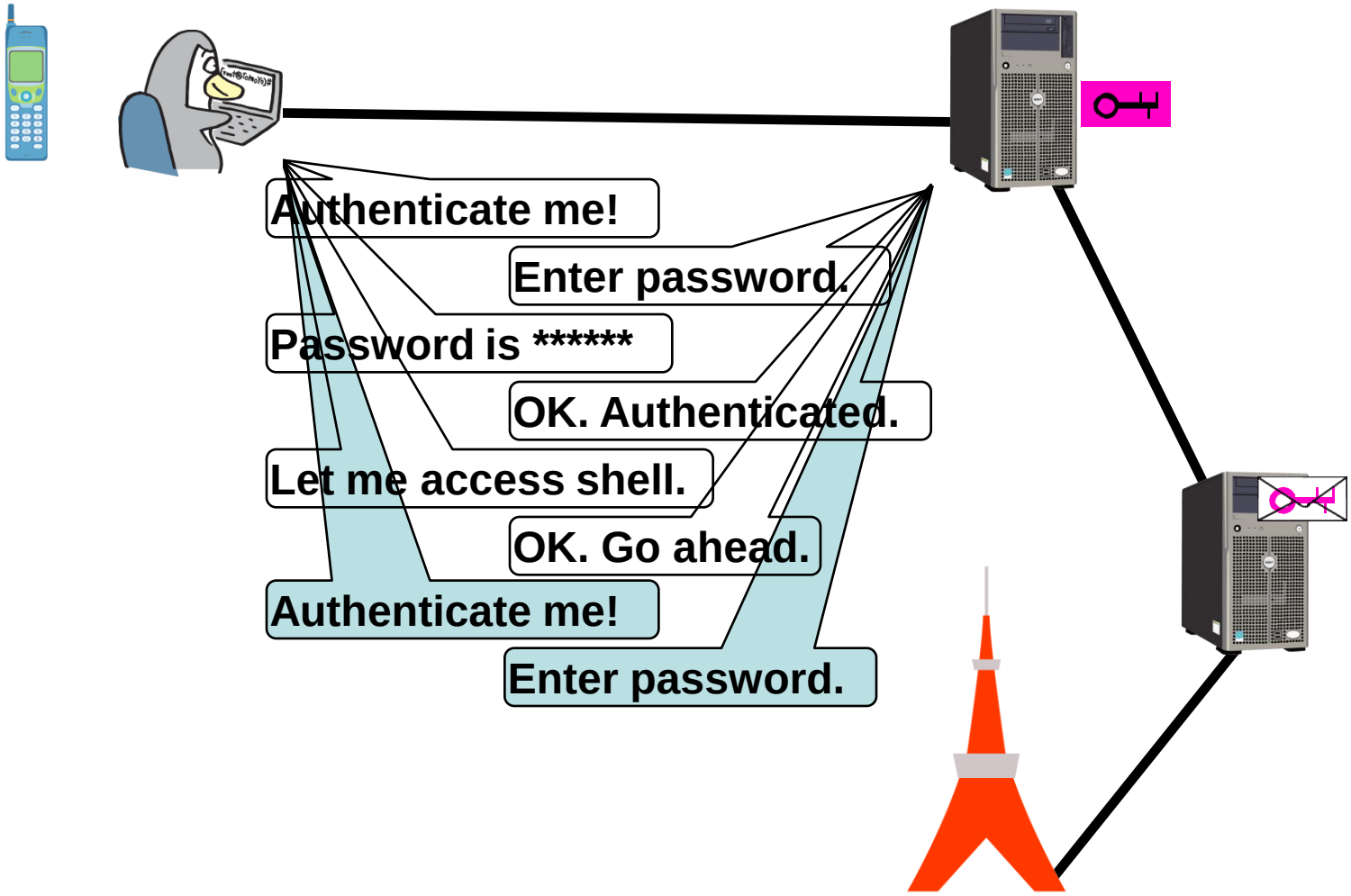

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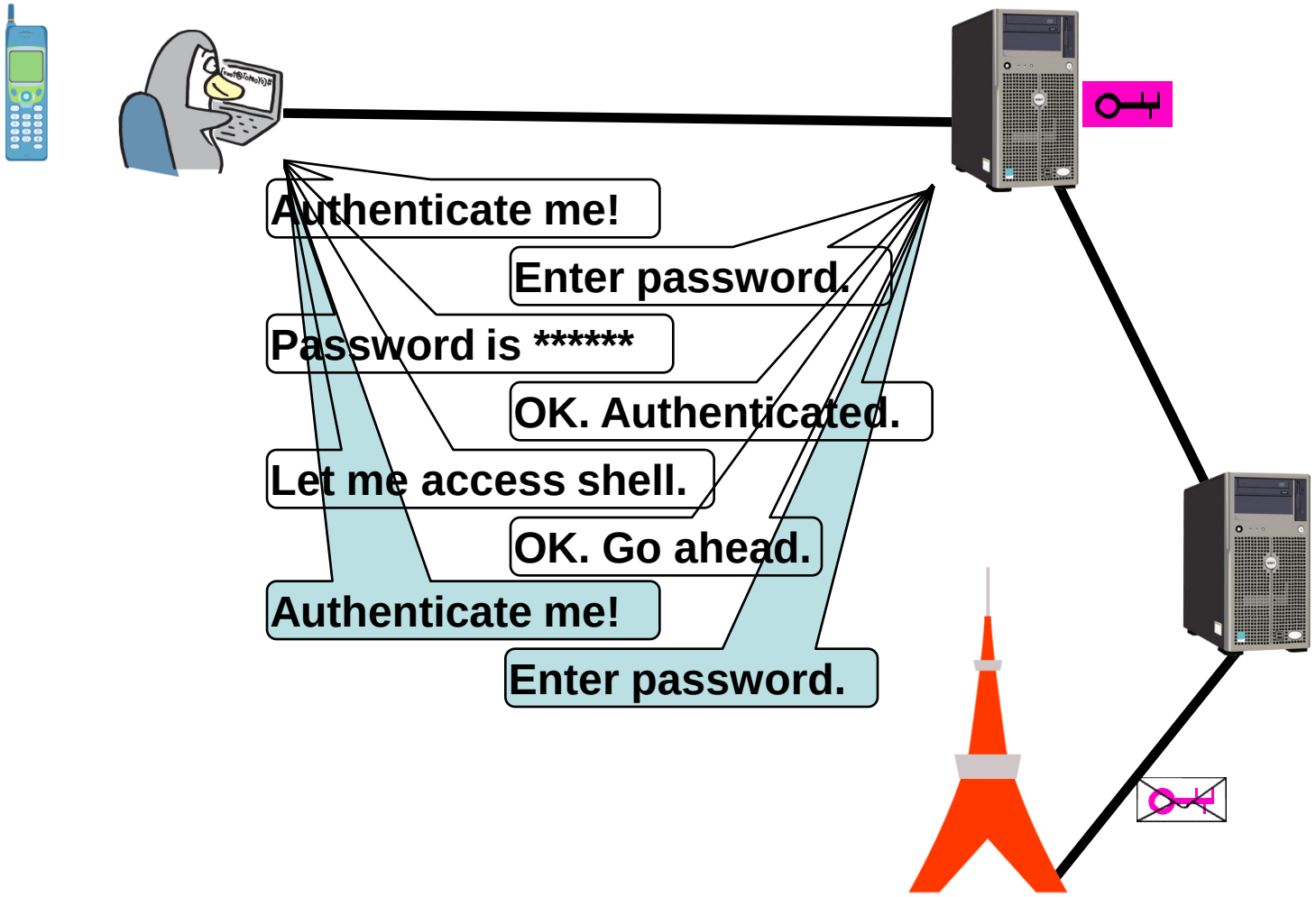

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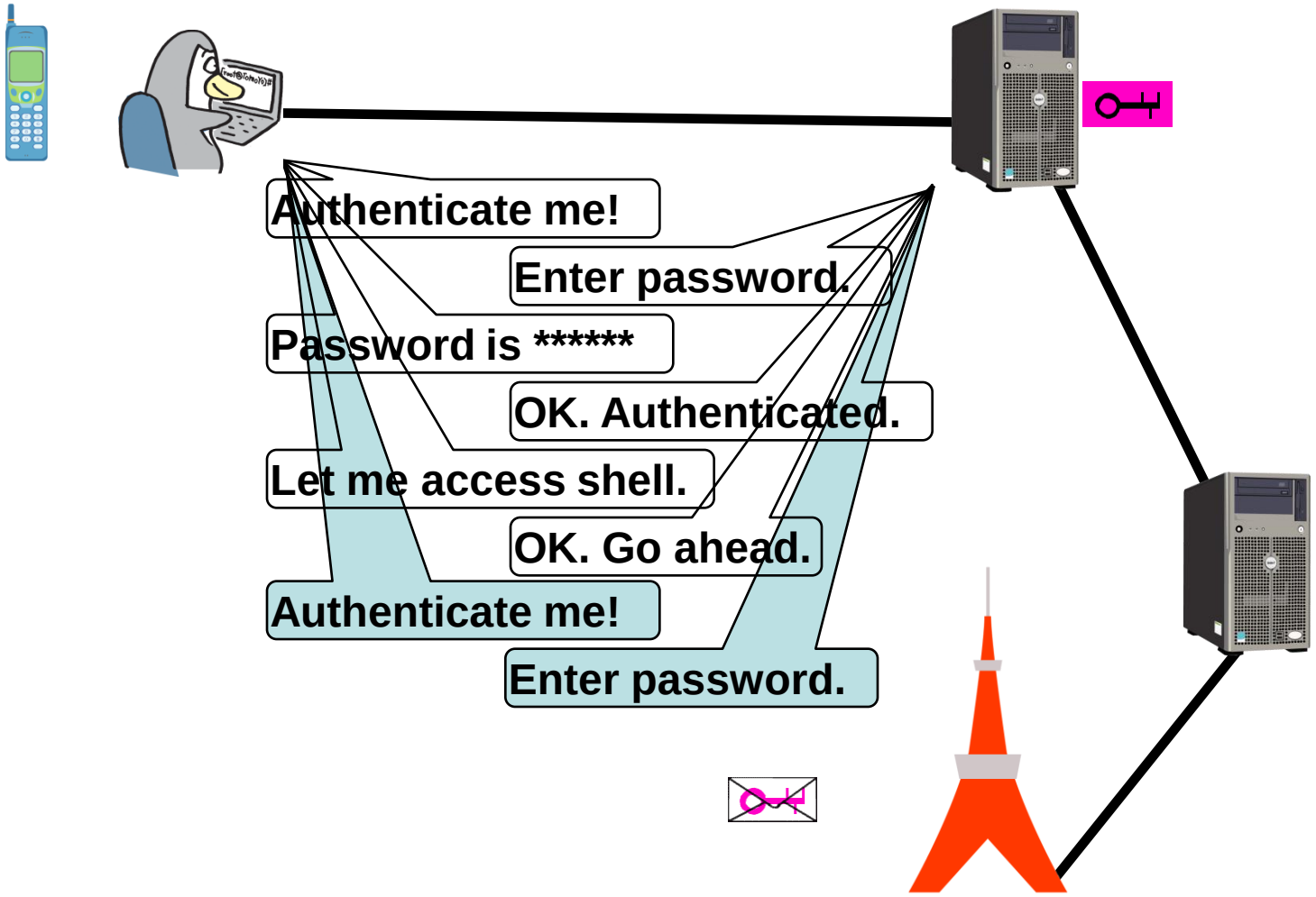

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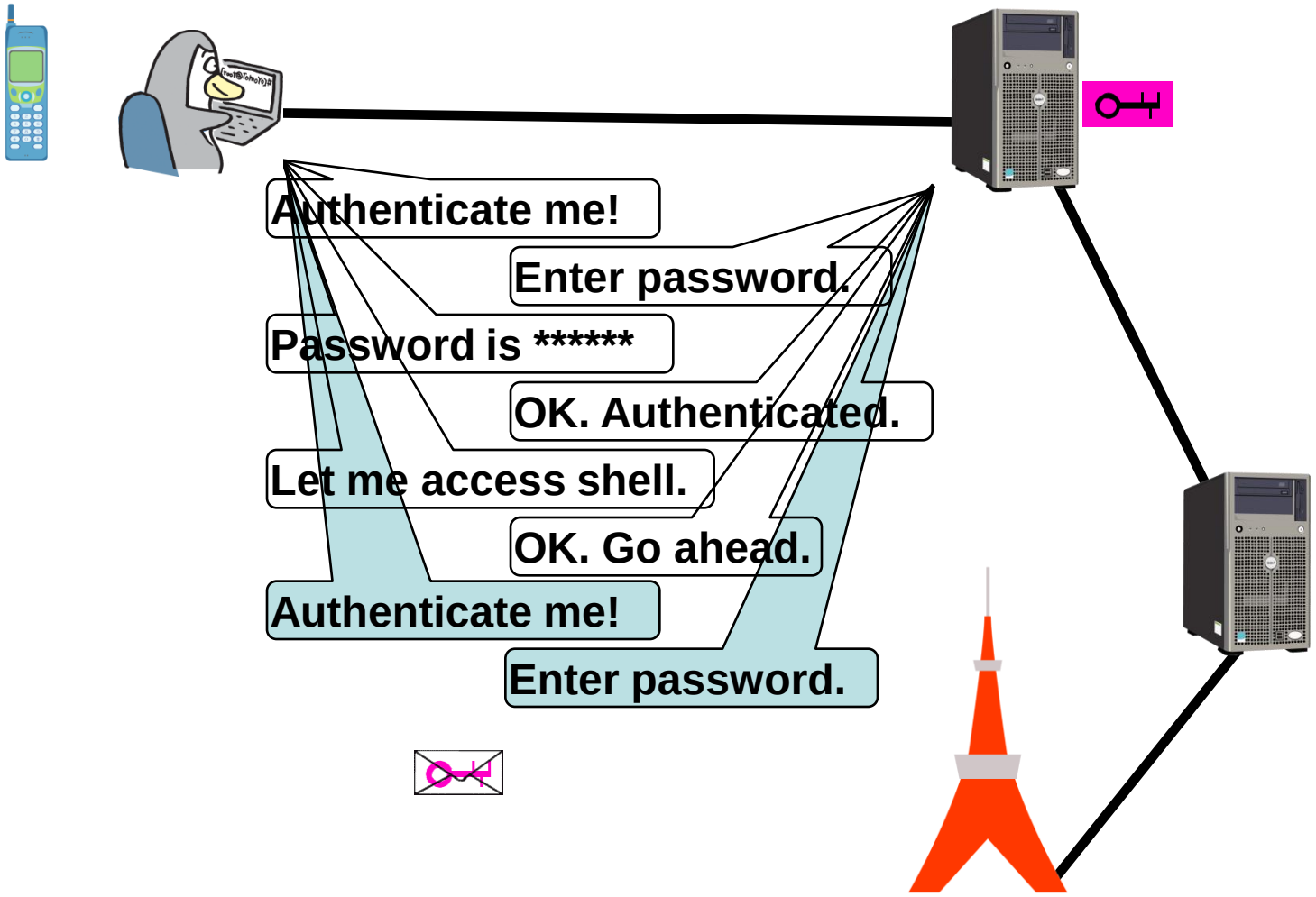

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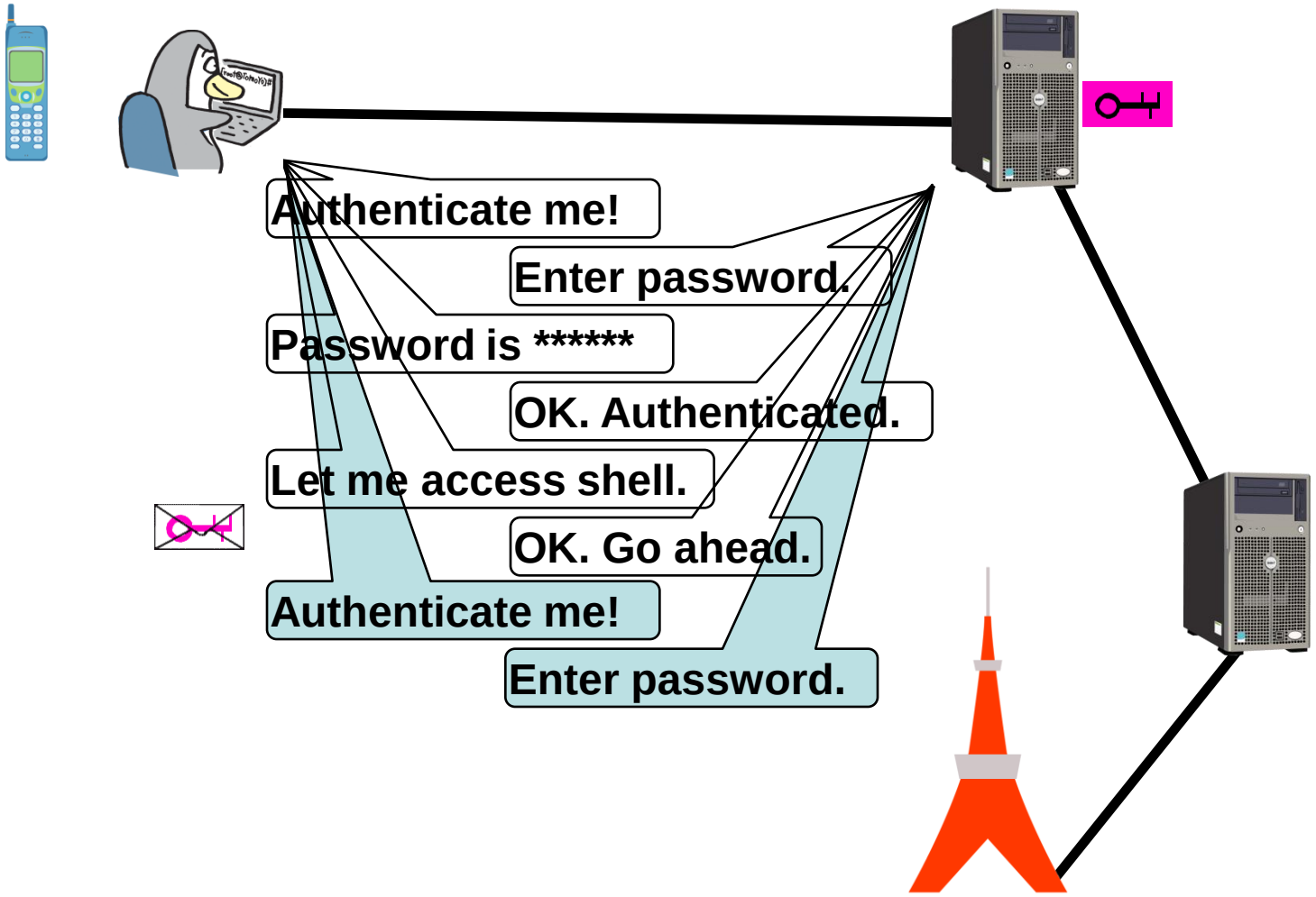

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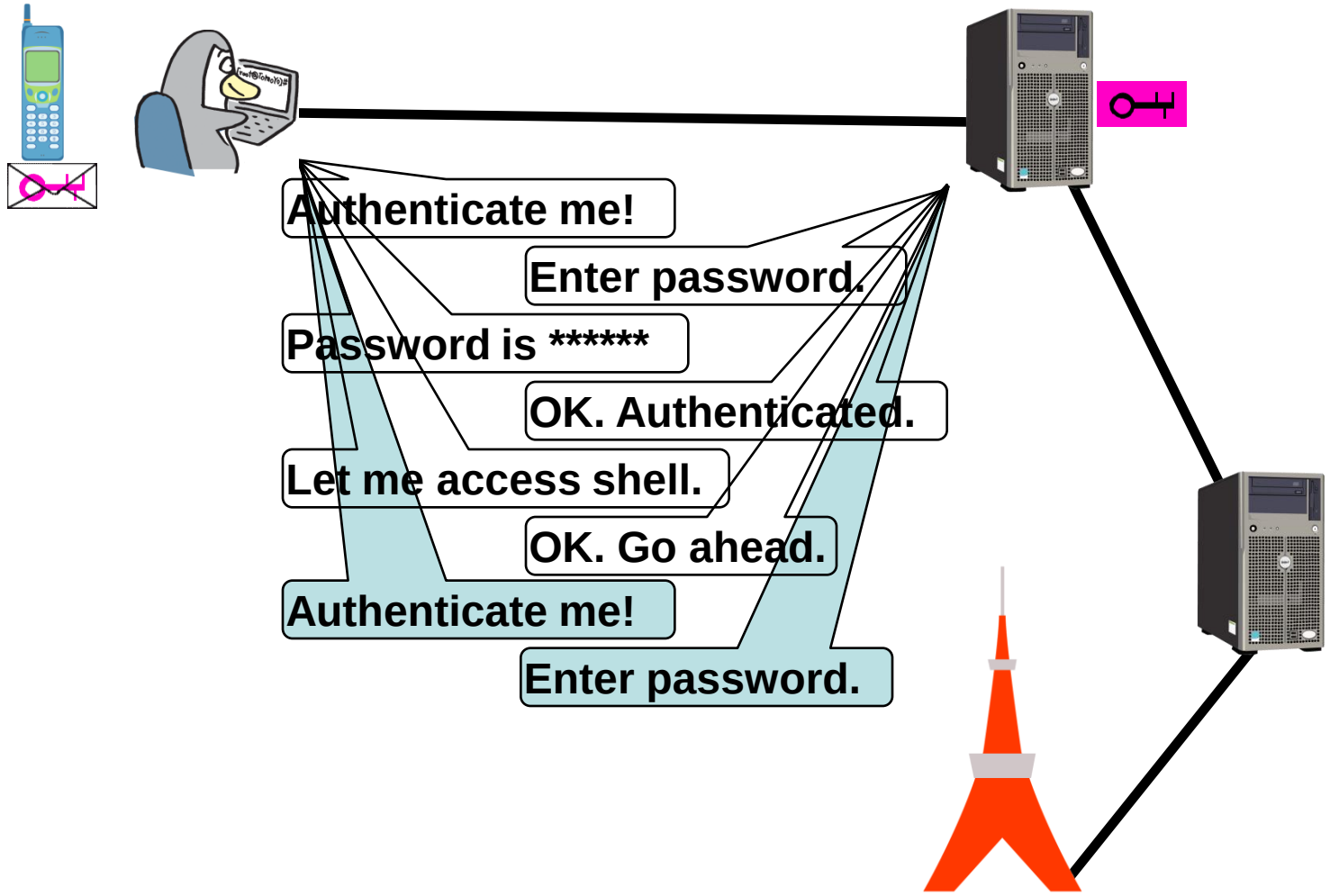

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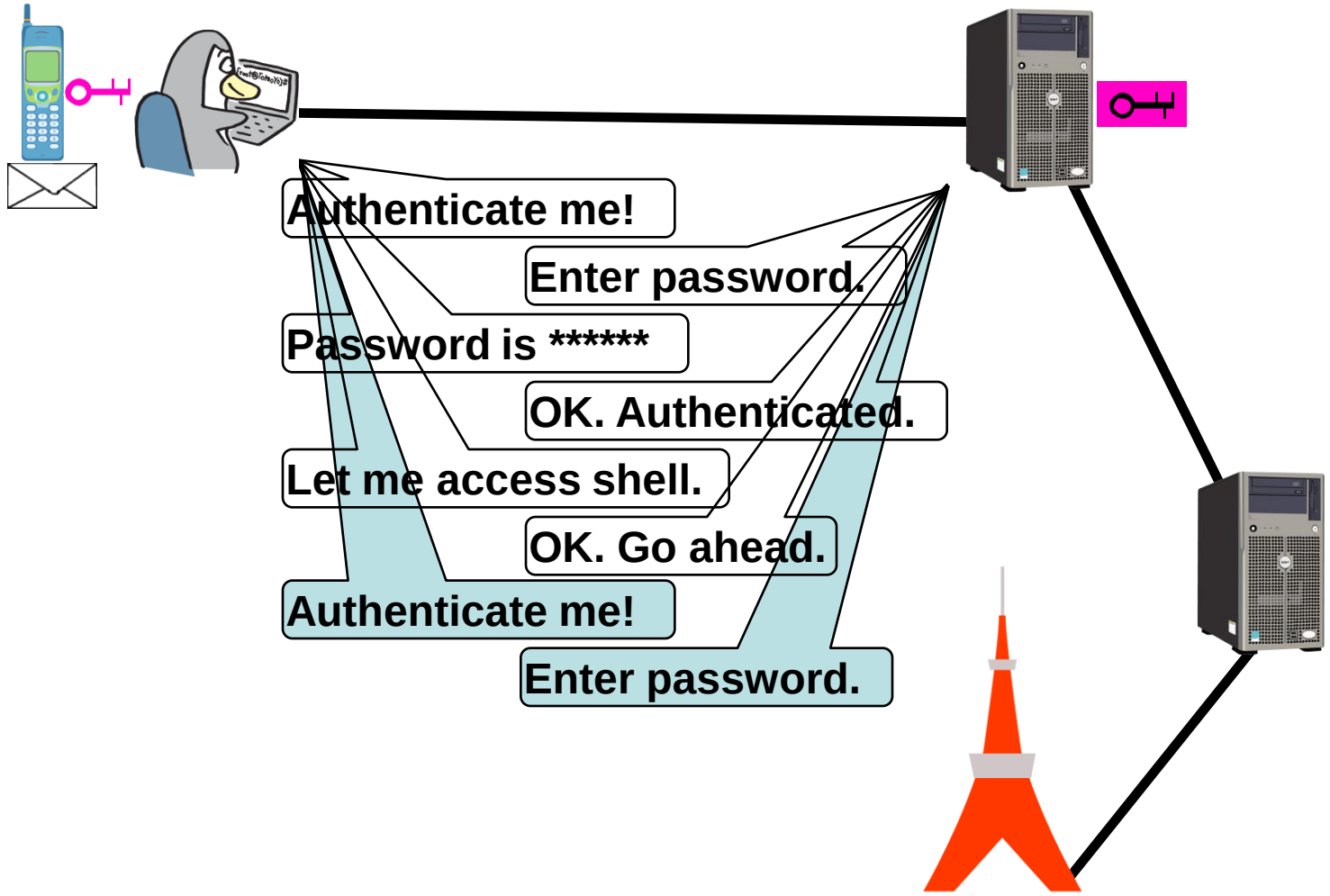

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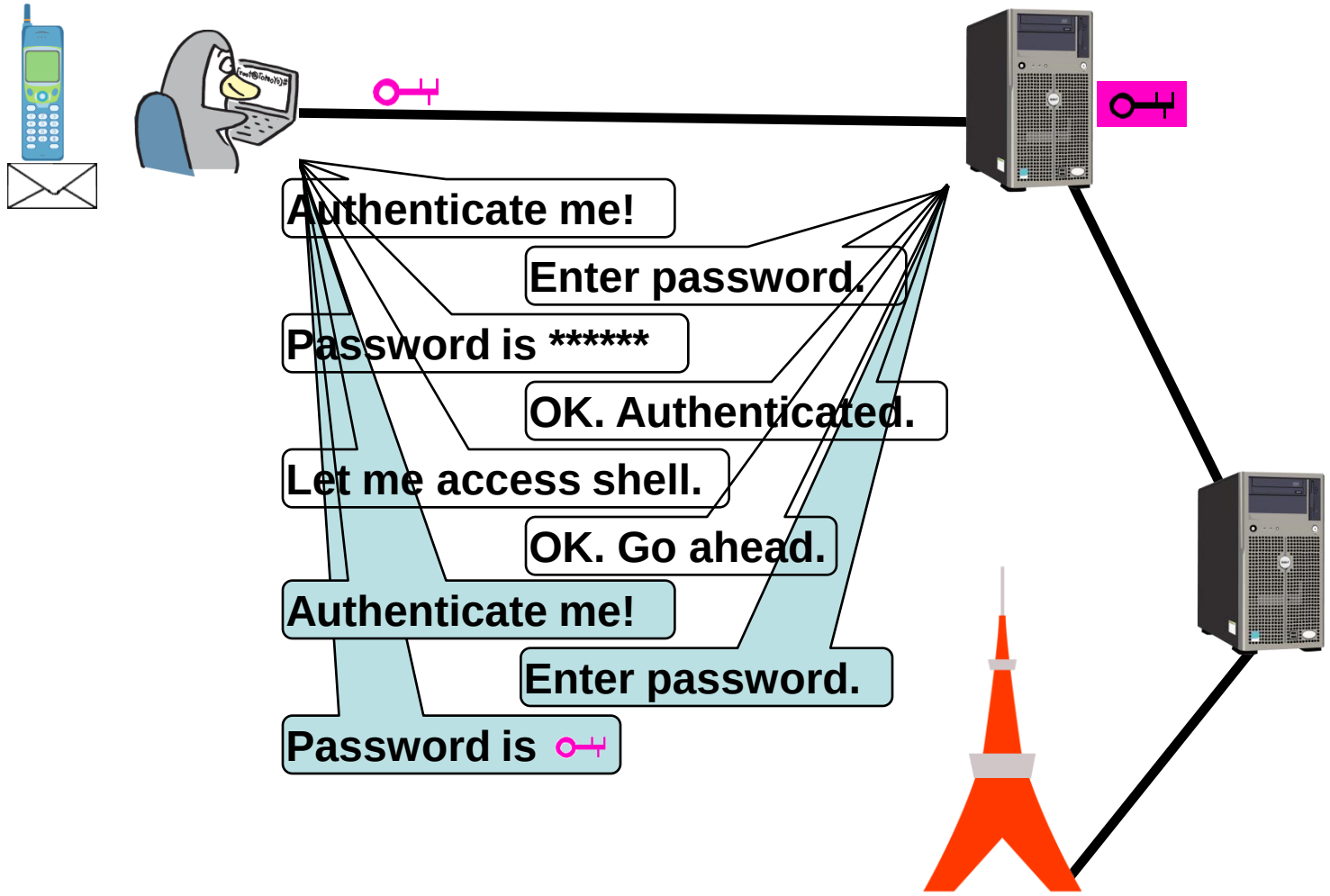

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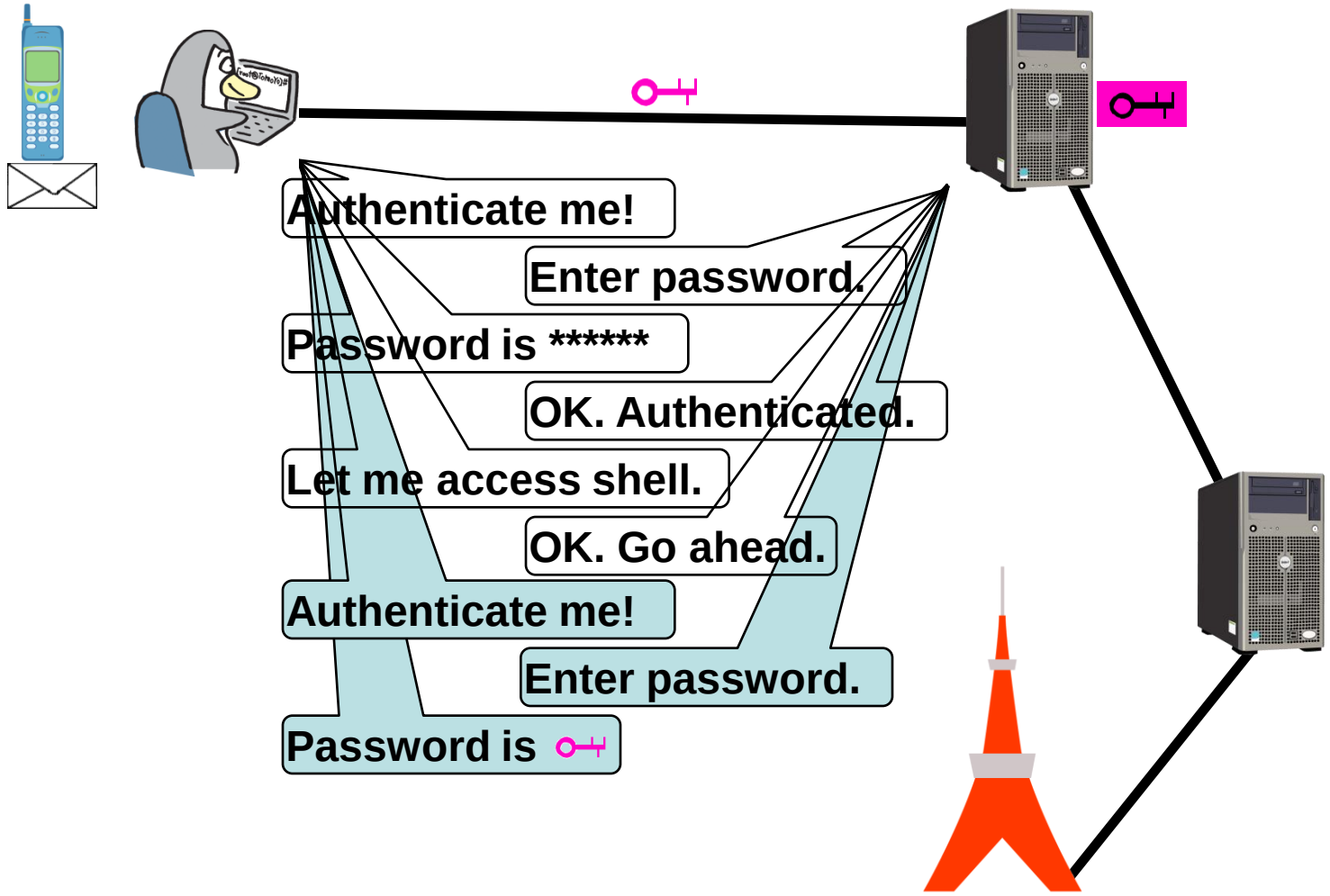

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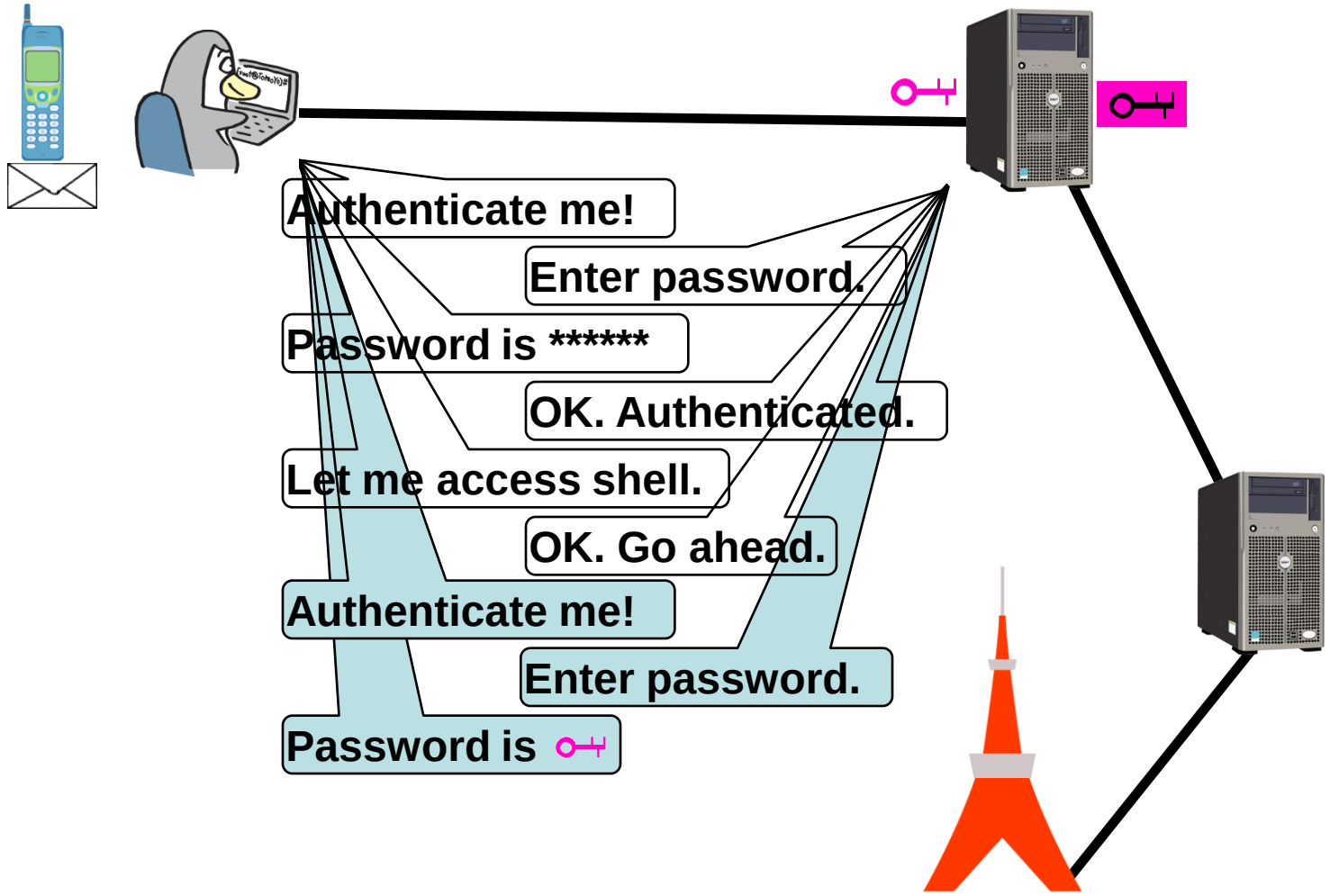

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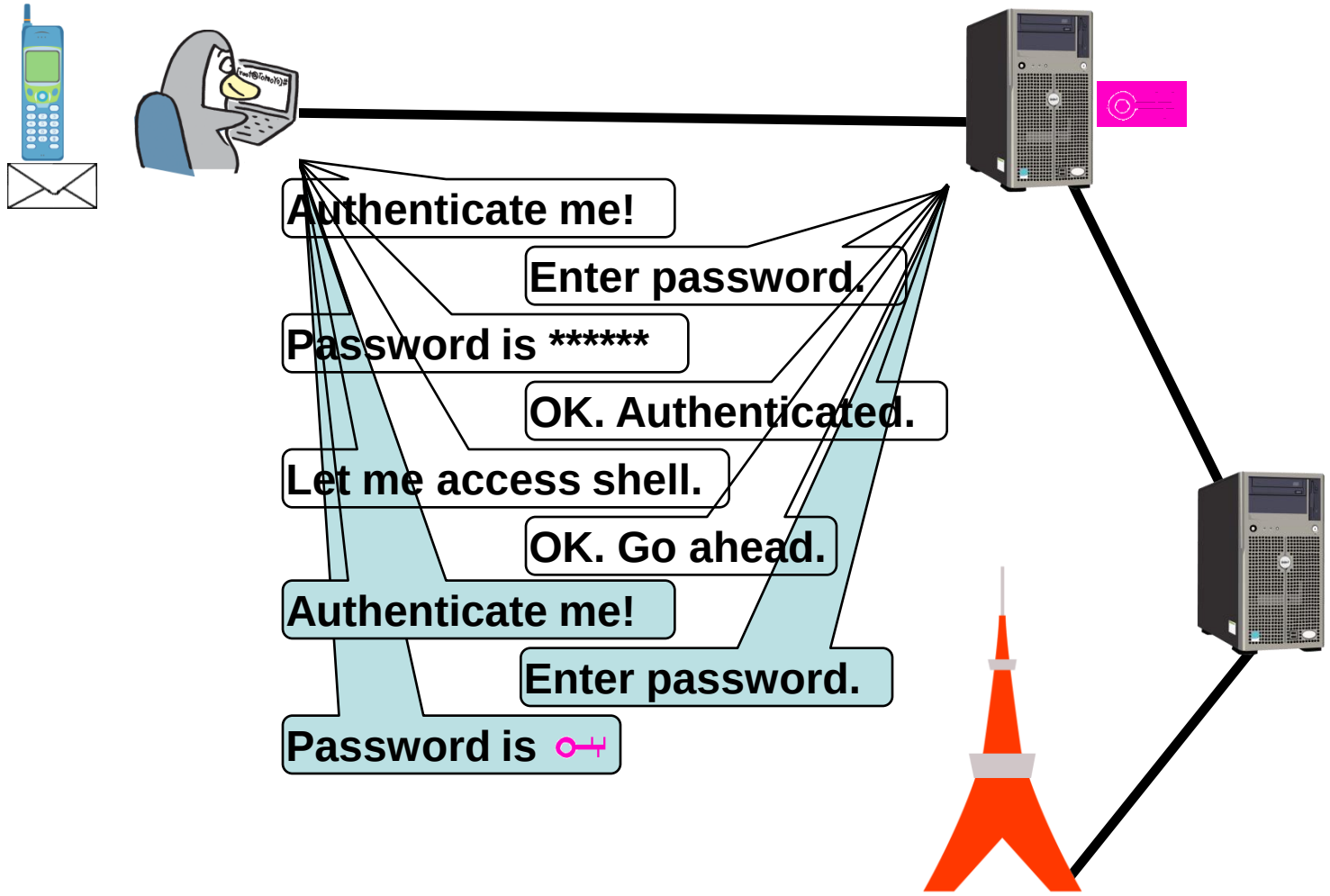

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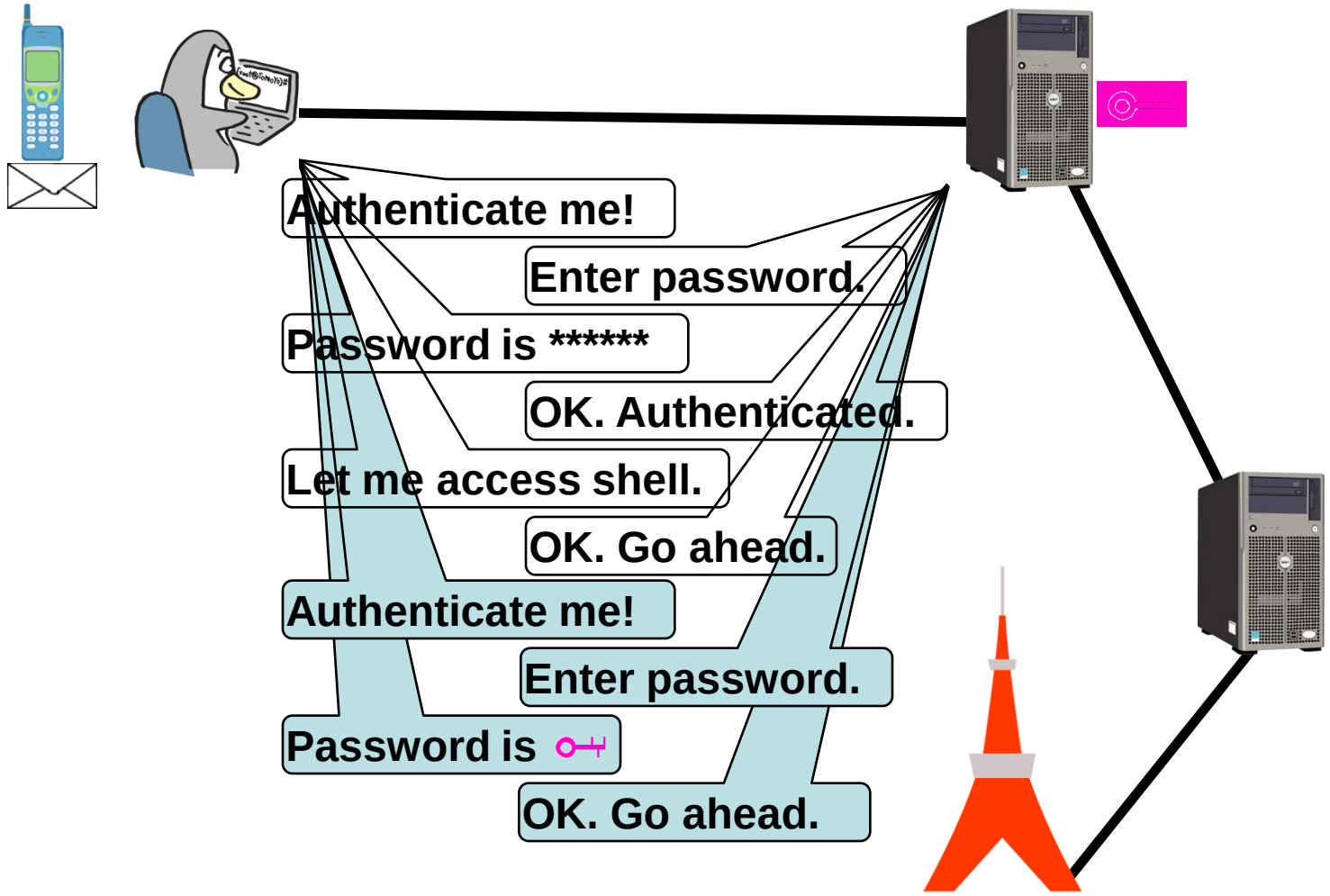

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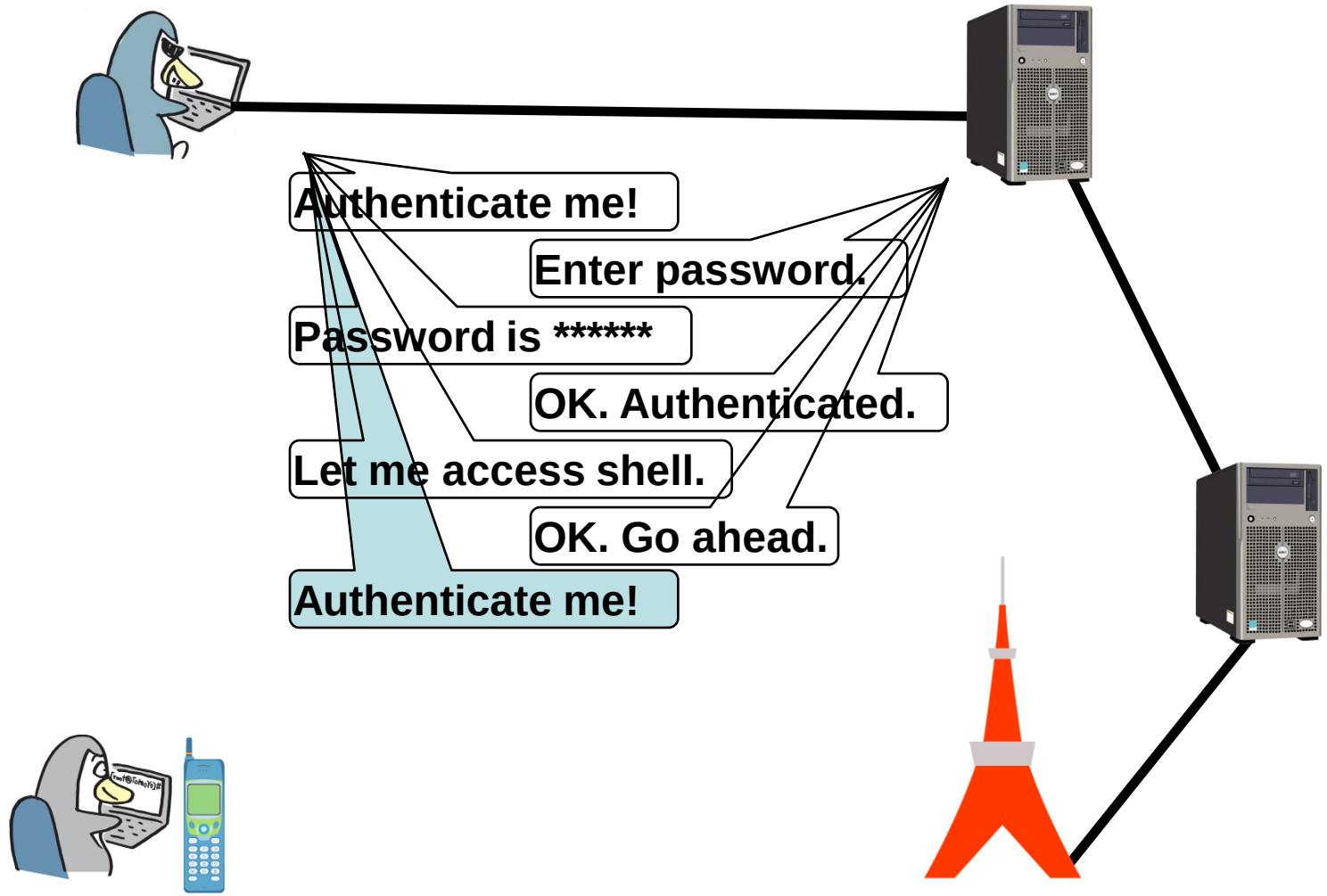

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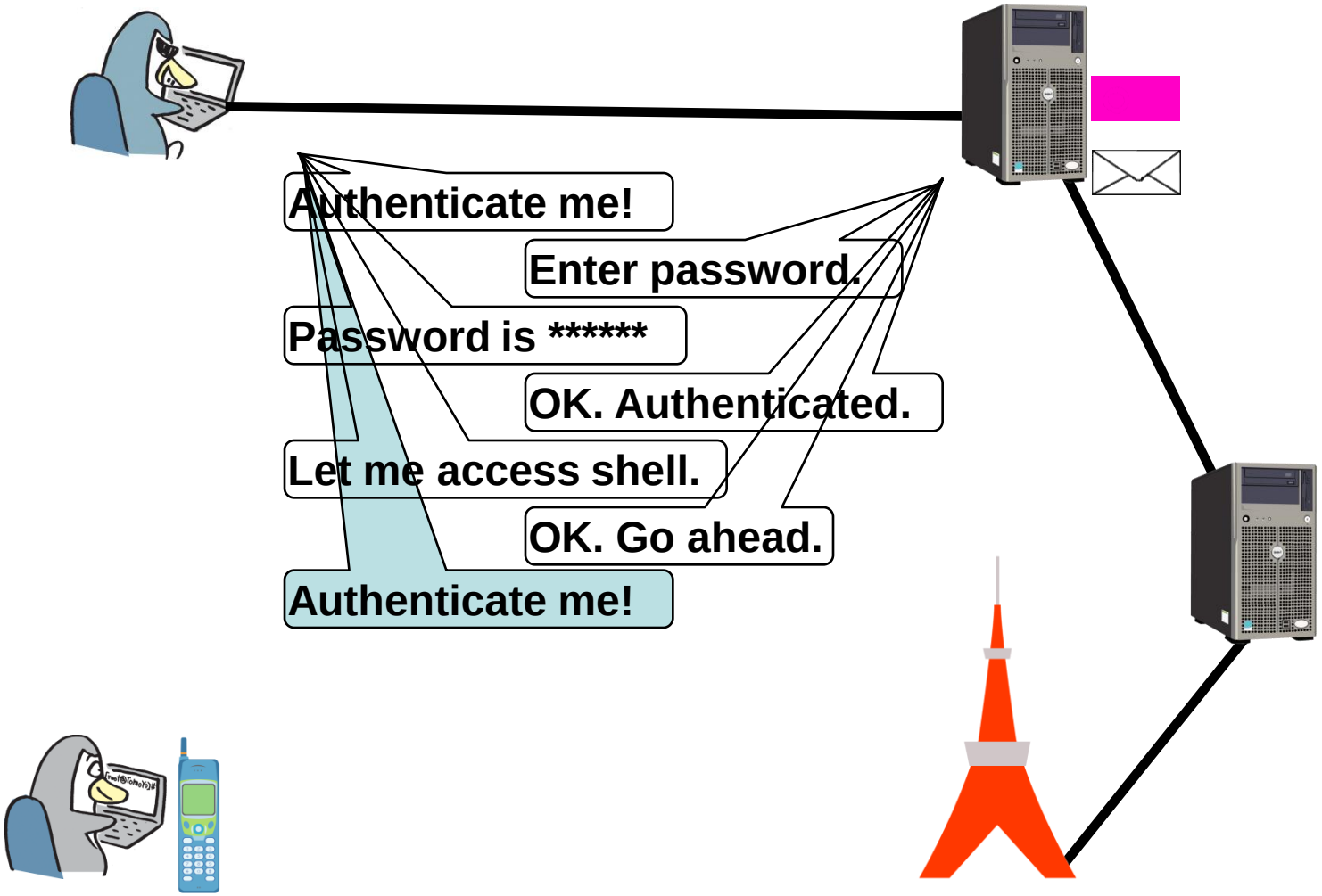

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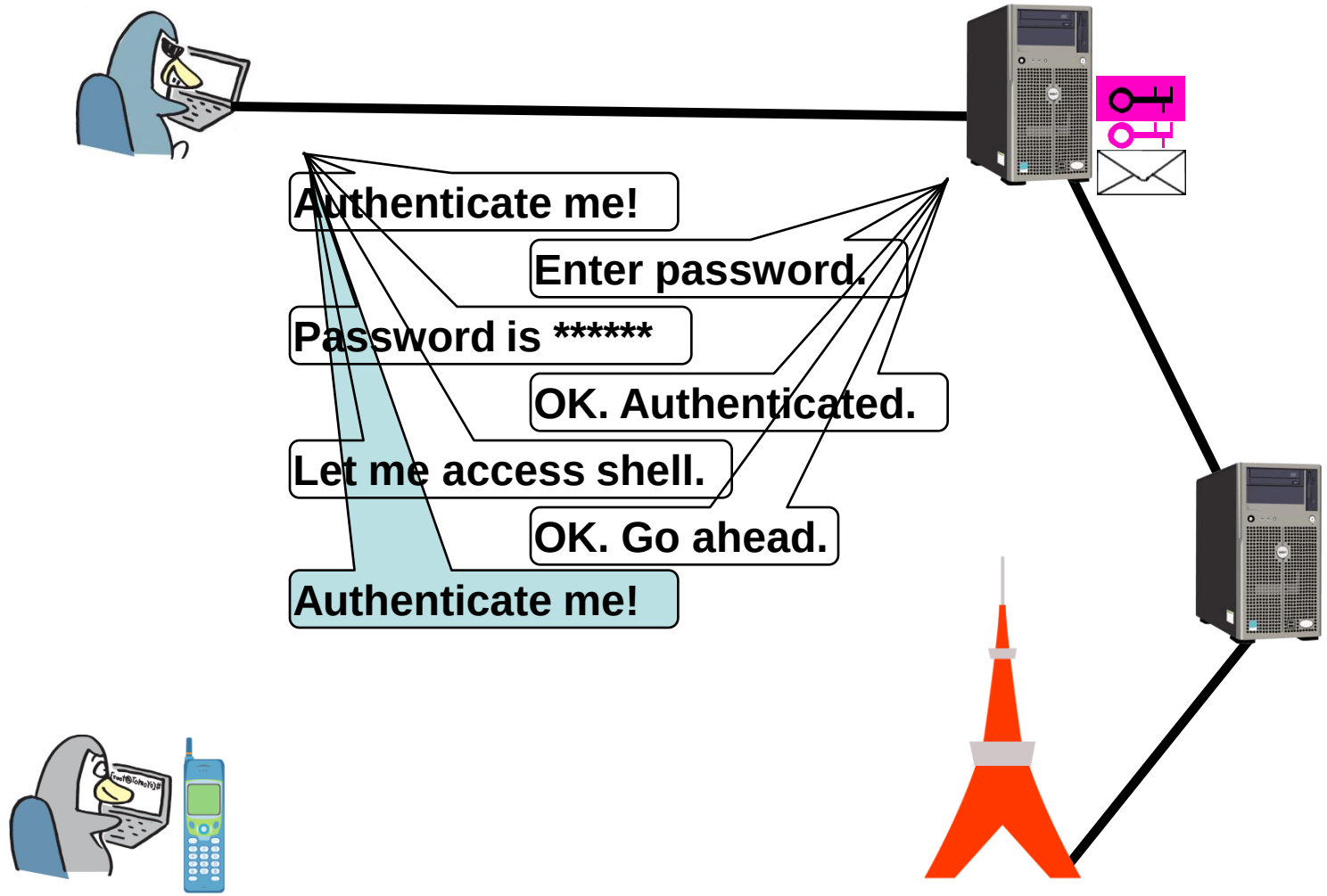

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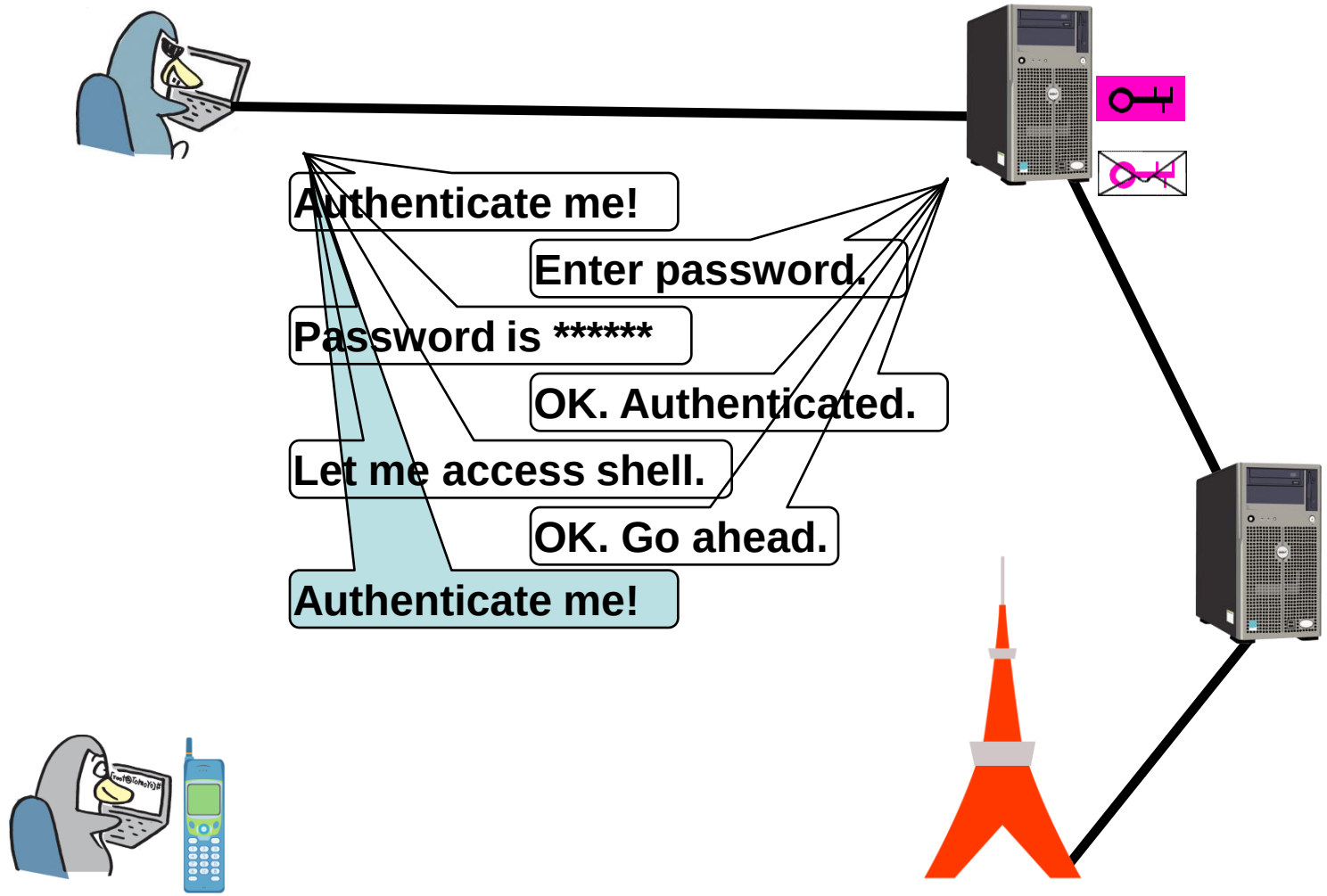

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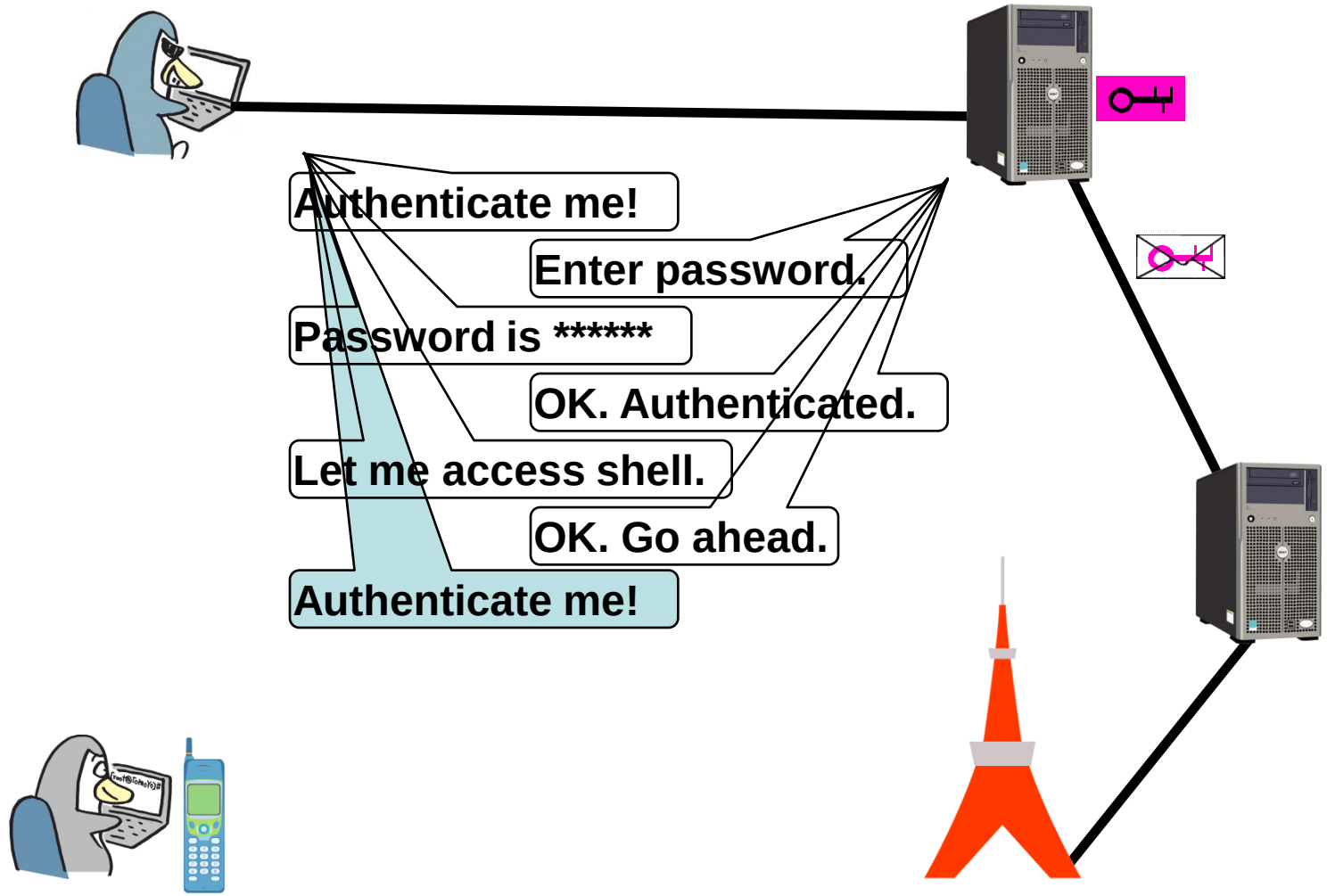

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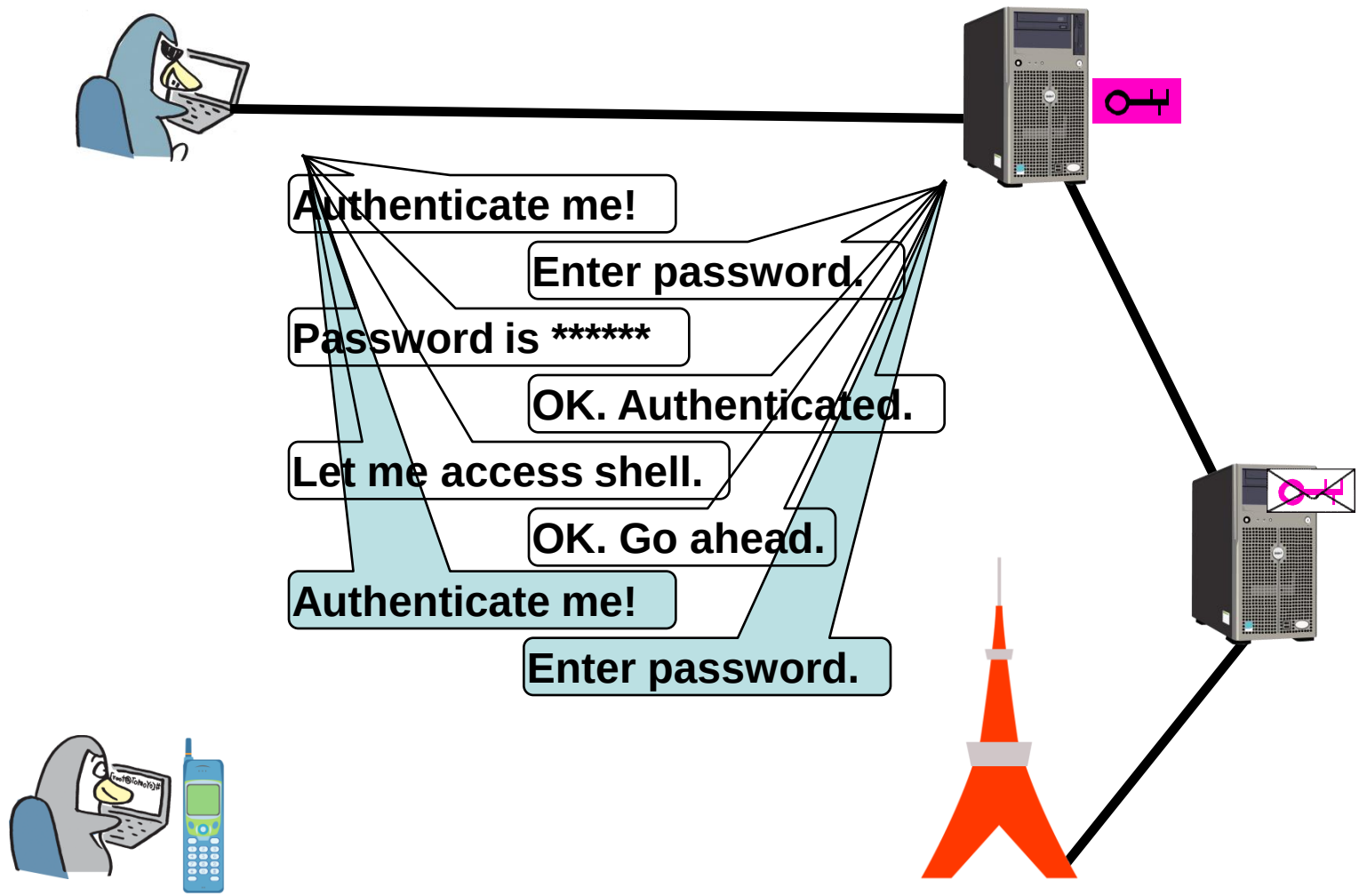

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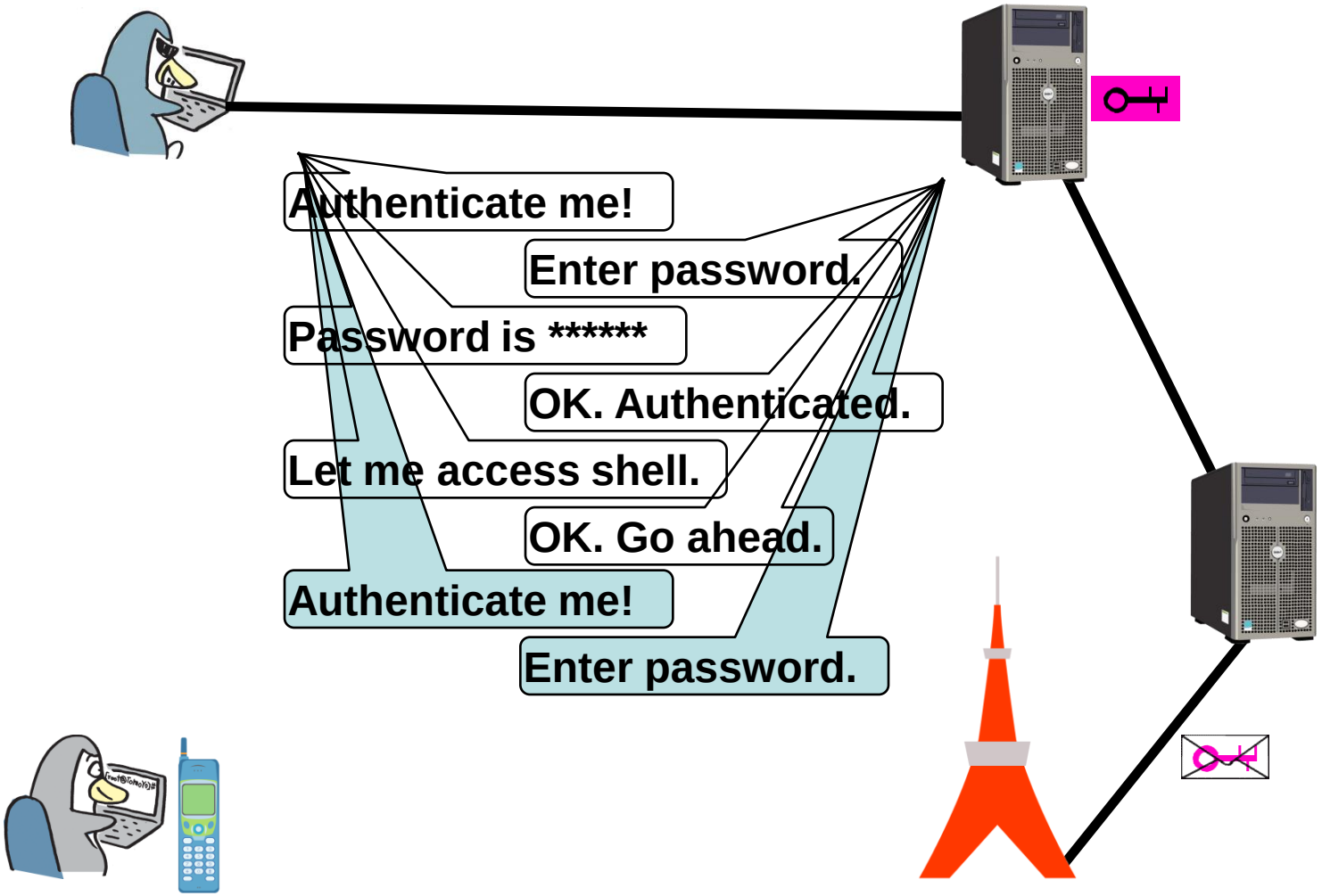

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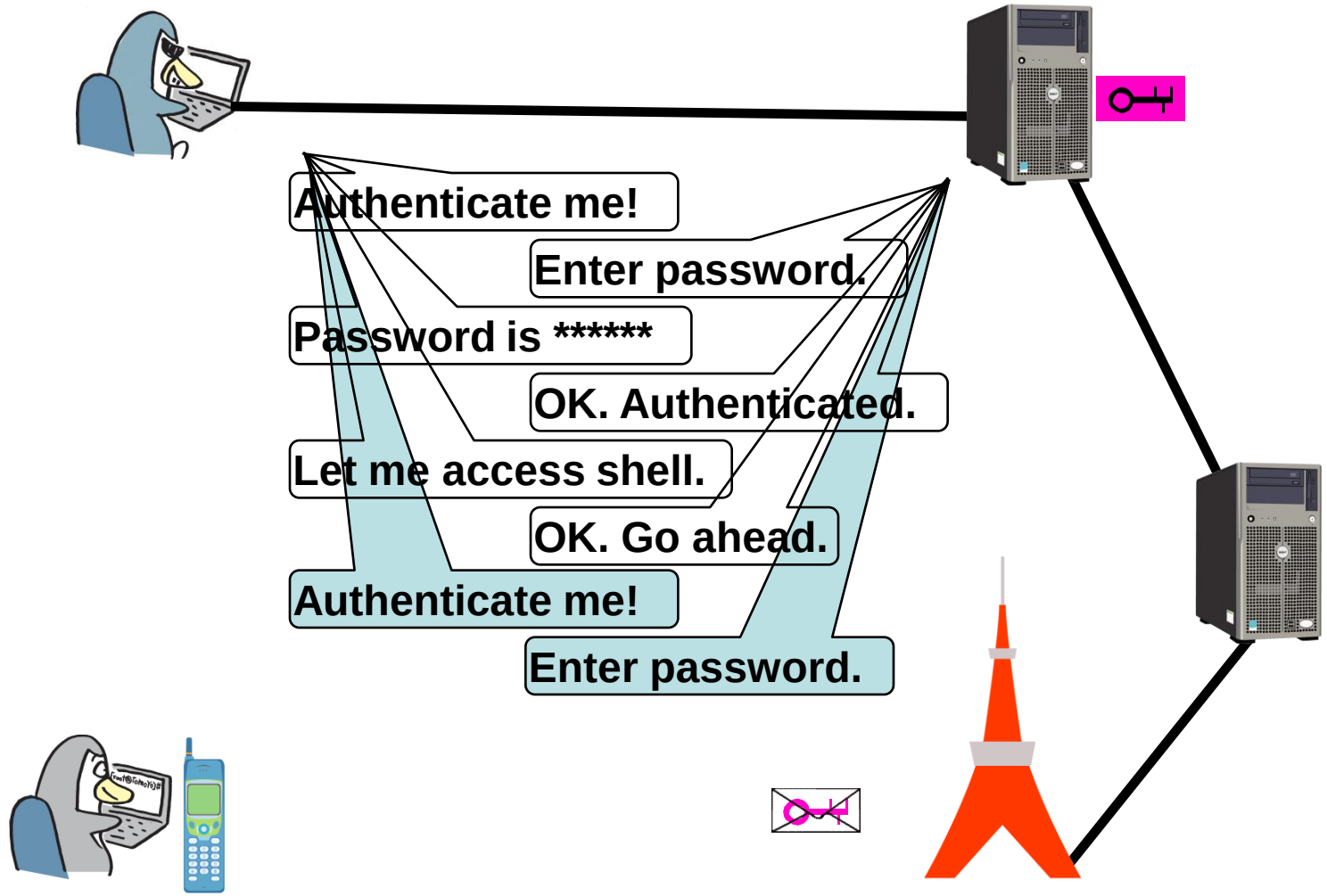

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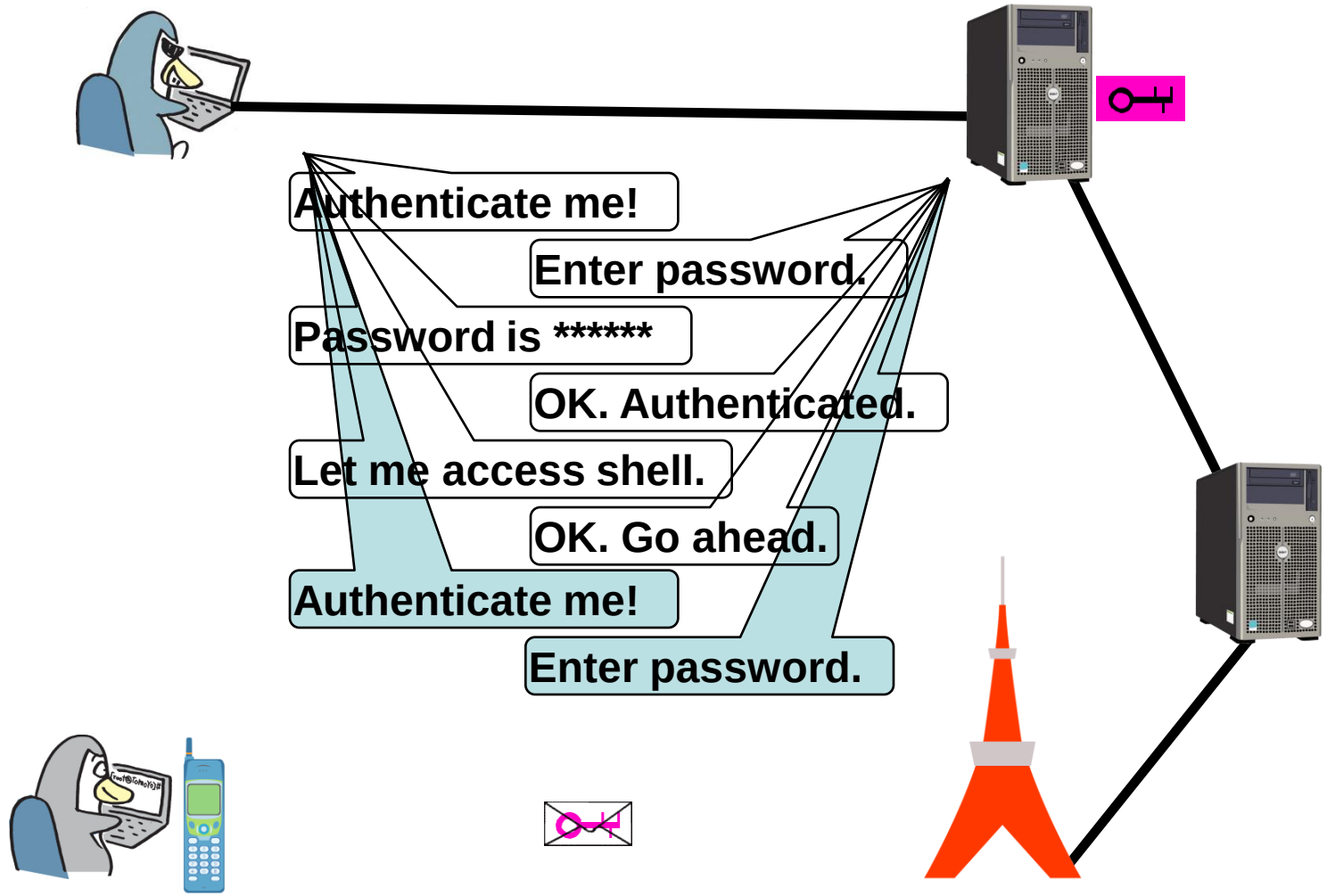

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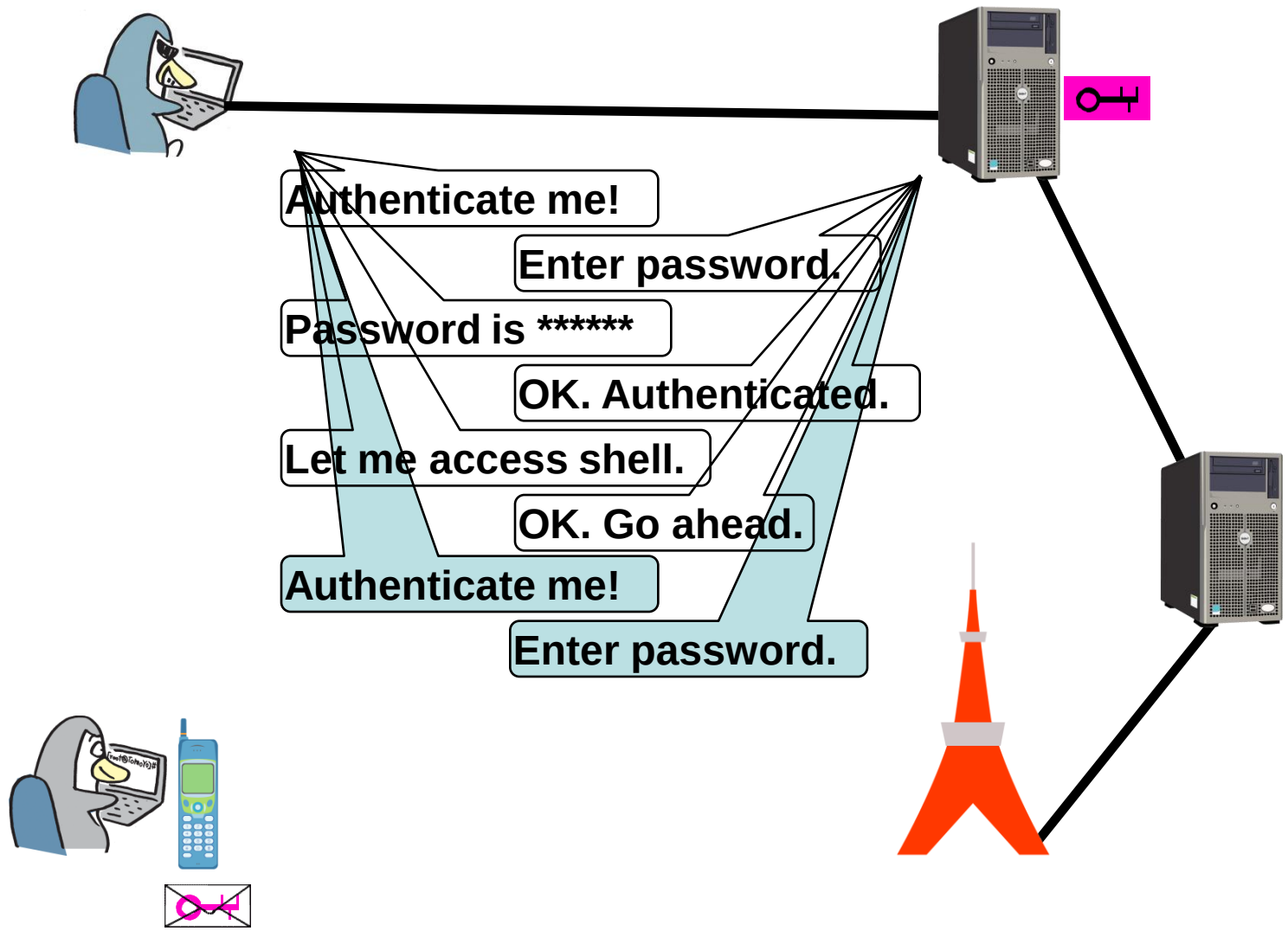

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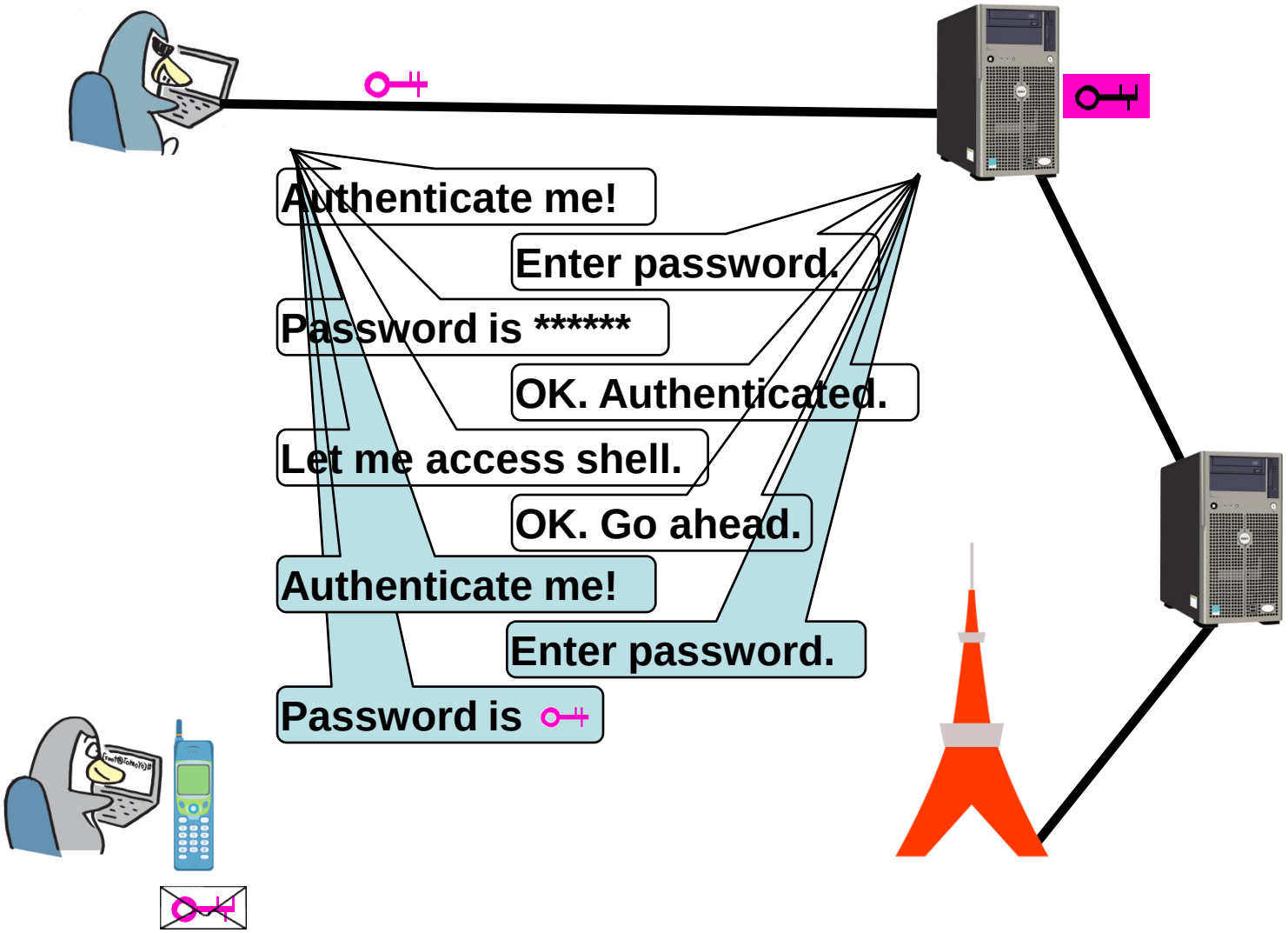
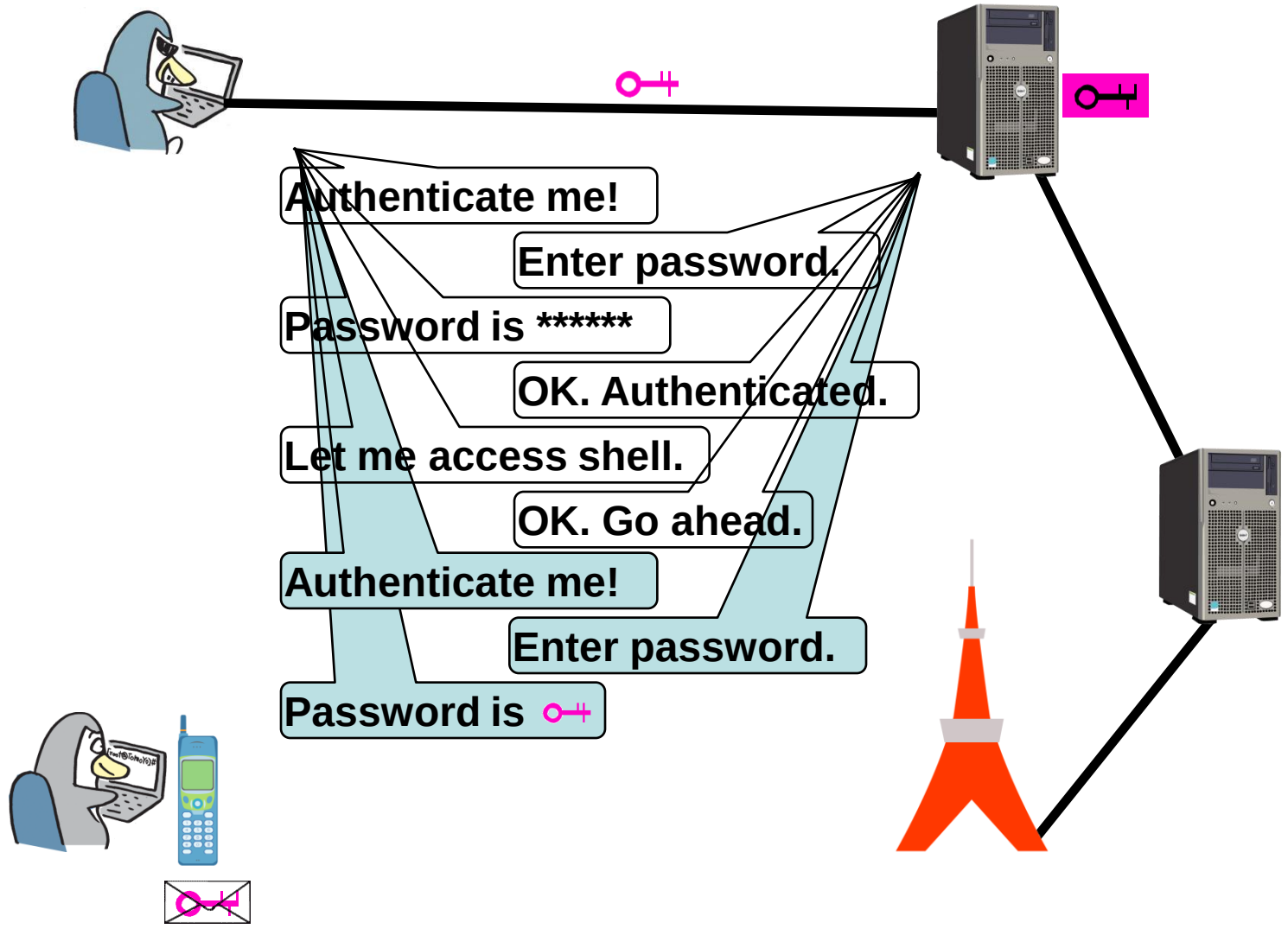


Case 2: Interactive shell session



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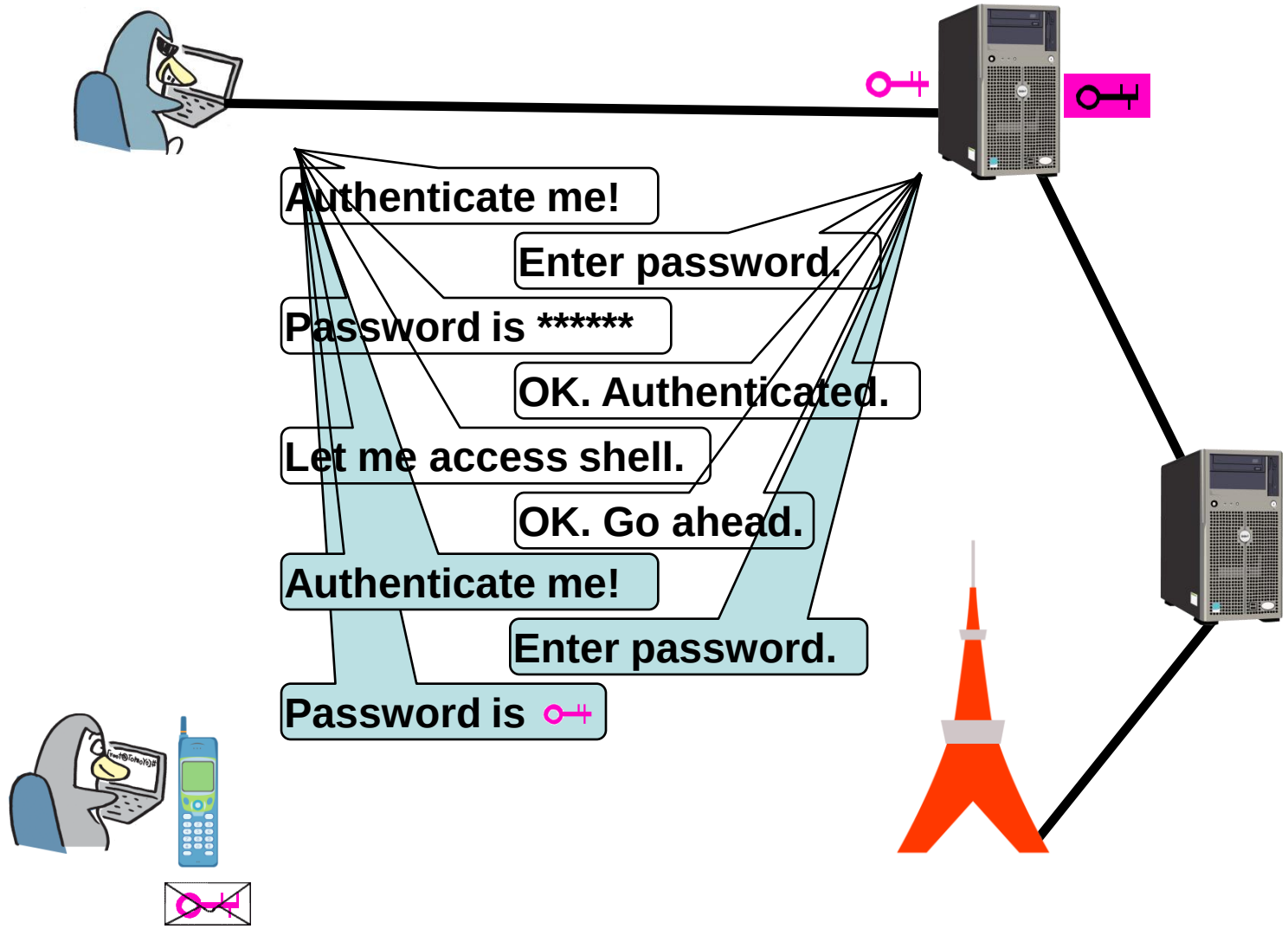
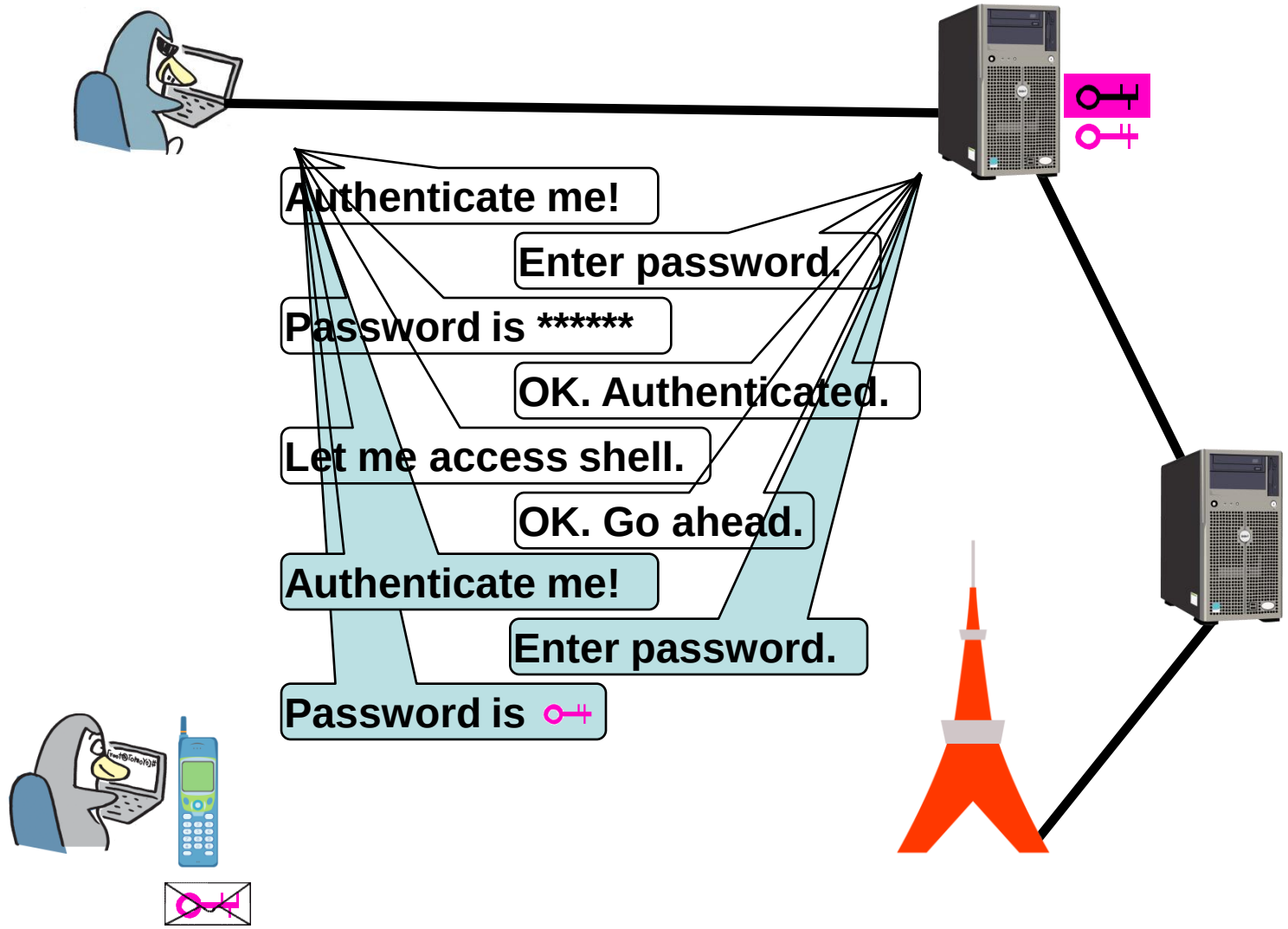
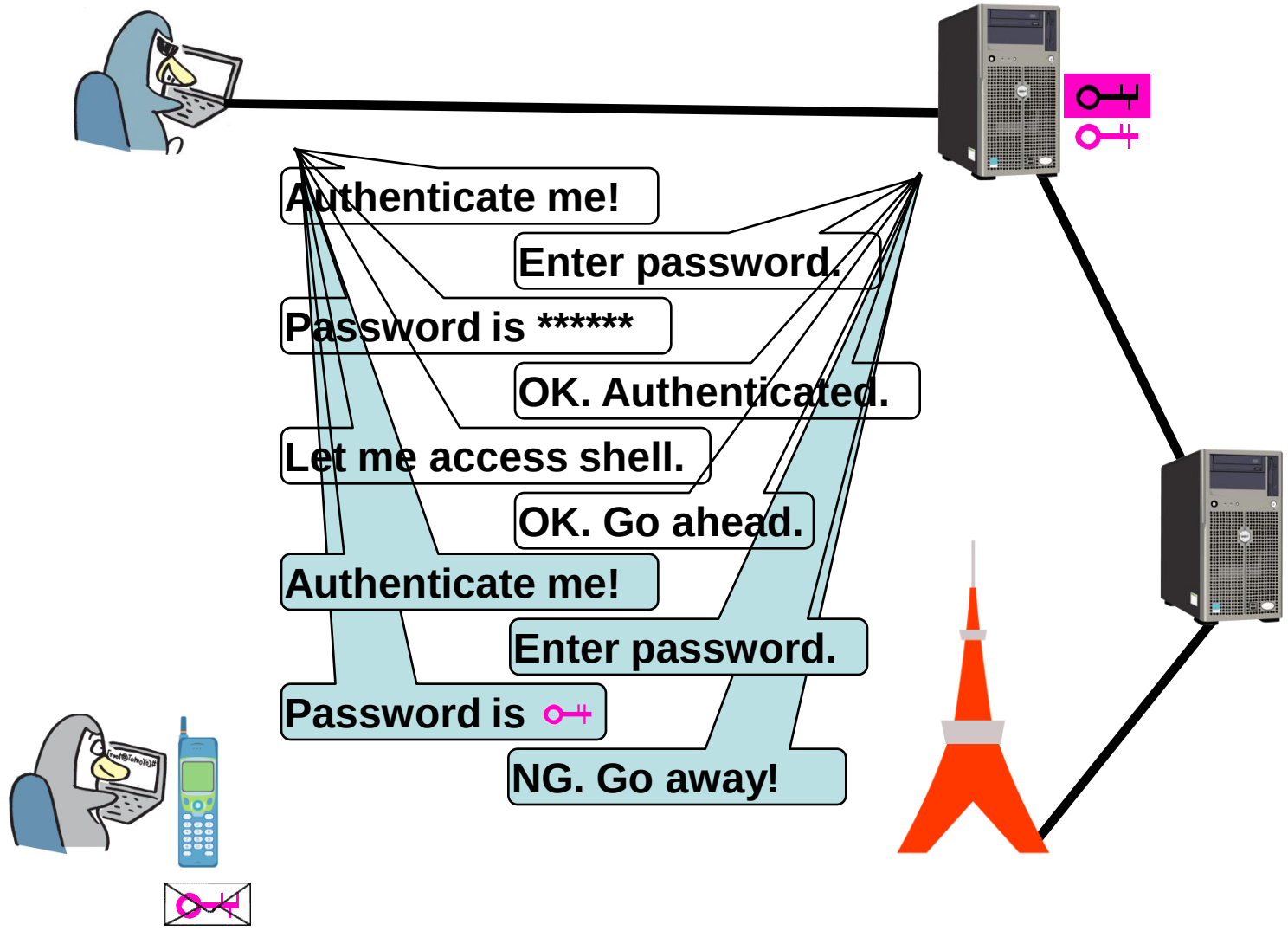


Case 2: Interactive shell session



Case 2: Interactive shell session



Case 2: Interactive shell session

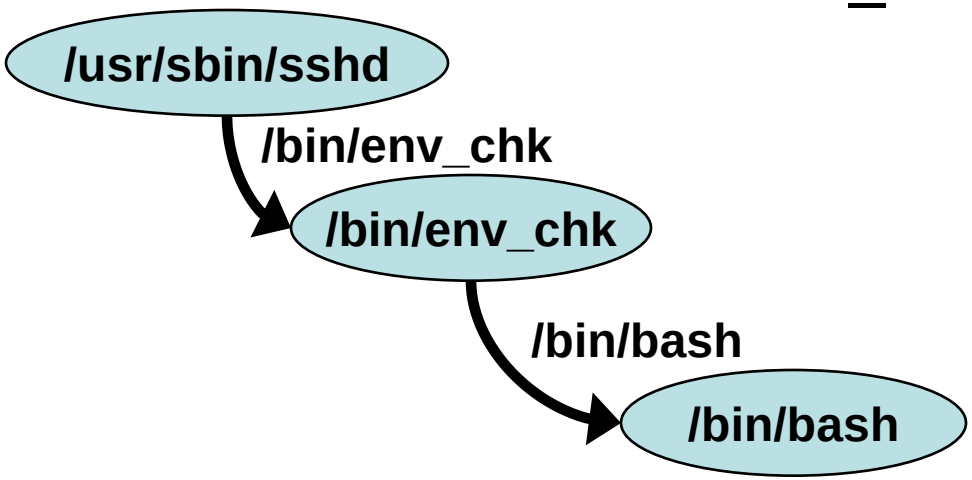
- Advantages
  - The process which generated OTP also verifies the OTP.
    - No need for time/counter synchronization mechanism.
    - OTP expires when the process dies.
  - No problem if OTP is leaked to anybody but the intruder.
    - OTP is valid for nobody but the user who created the process.

Case 2: Interactive shell session

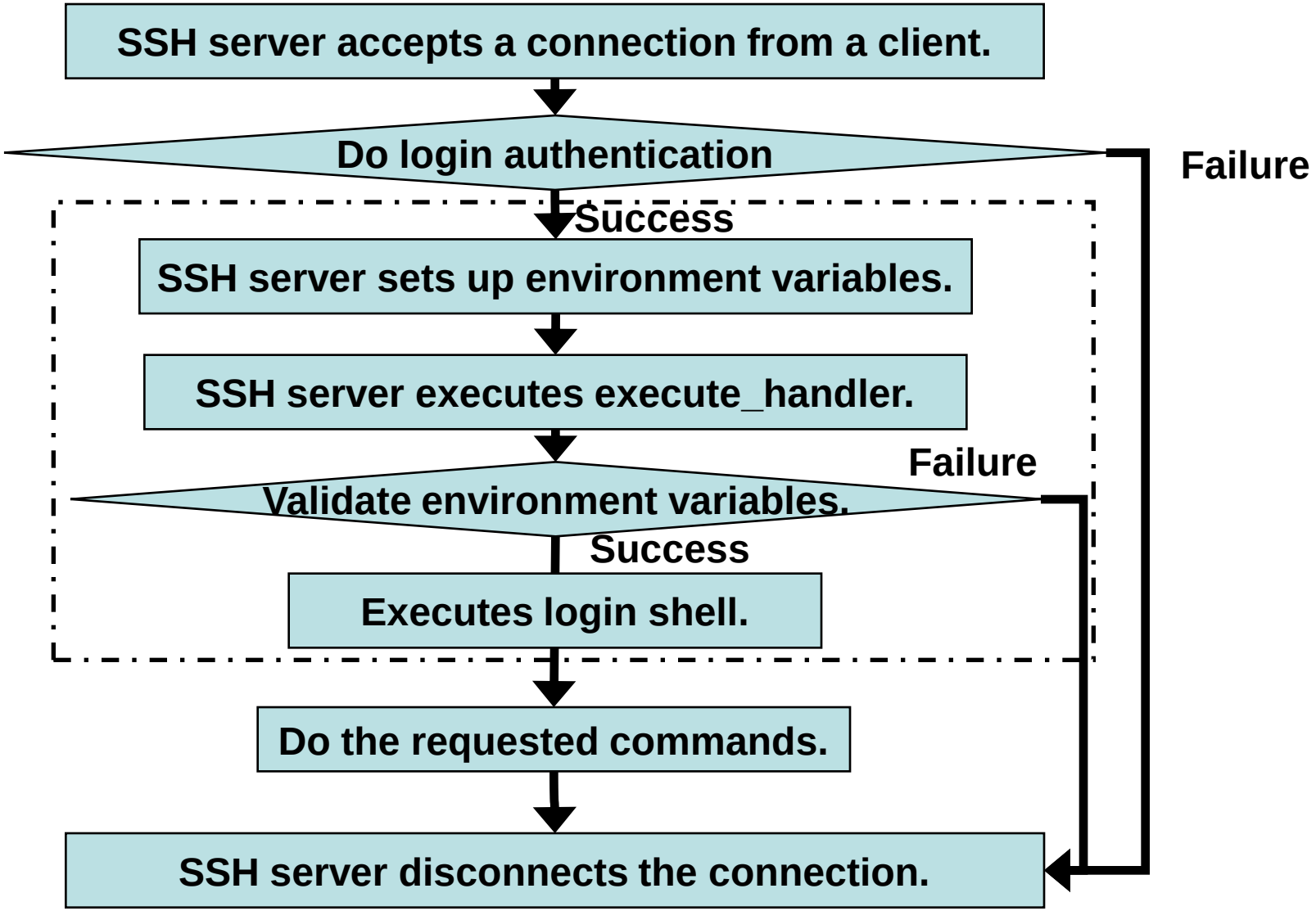
- Disadvantages
  - You need to receive mail.
    - You need to carry a mail receiver (e.g. cell-phone).
  - You need to send mail.
    - You need to provide SMTP service or equivalent (e.g. sendmail CGI program on WEB server).

Case 3: Non-interactive shell session

- Utilize environment variables.
  - What we need
    - SSH server's AcceptEnv directive
    - SSH client's SendEnv directive
    - own program /bin/env_check
    - TOMOYO Linux's execute_handler directive



Case 3: Non-interactive shell session



Case 3: Non-interactive shell session

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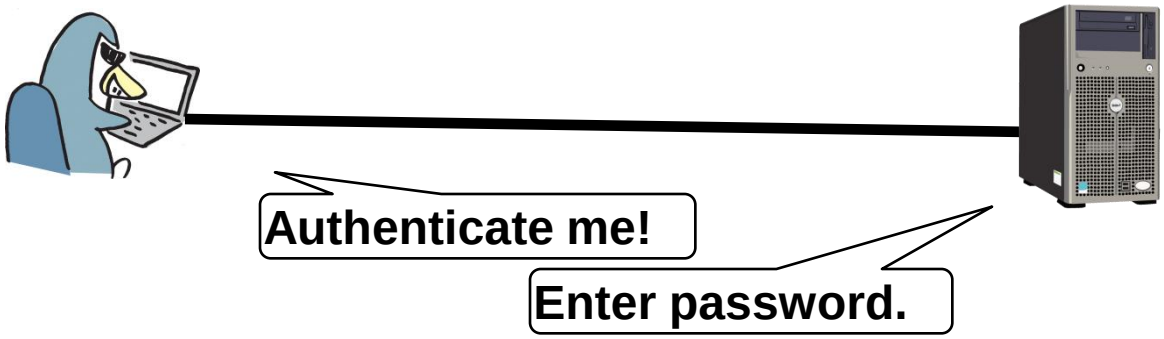
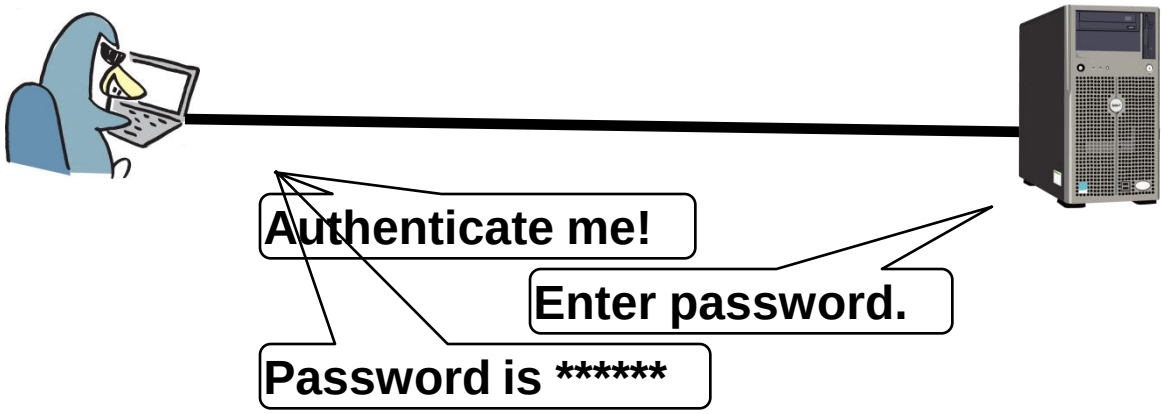


Case 3: Non-interactive shell session



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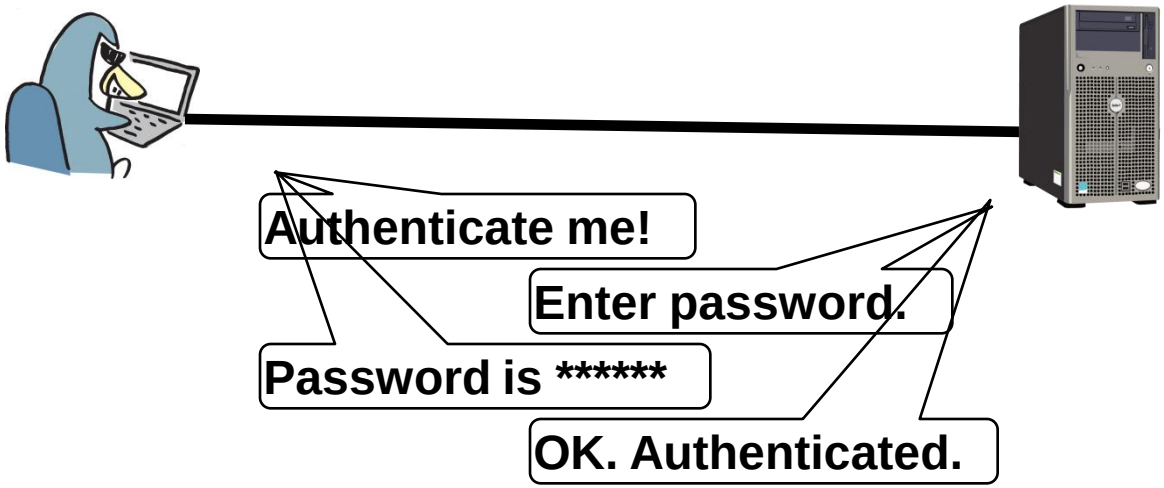
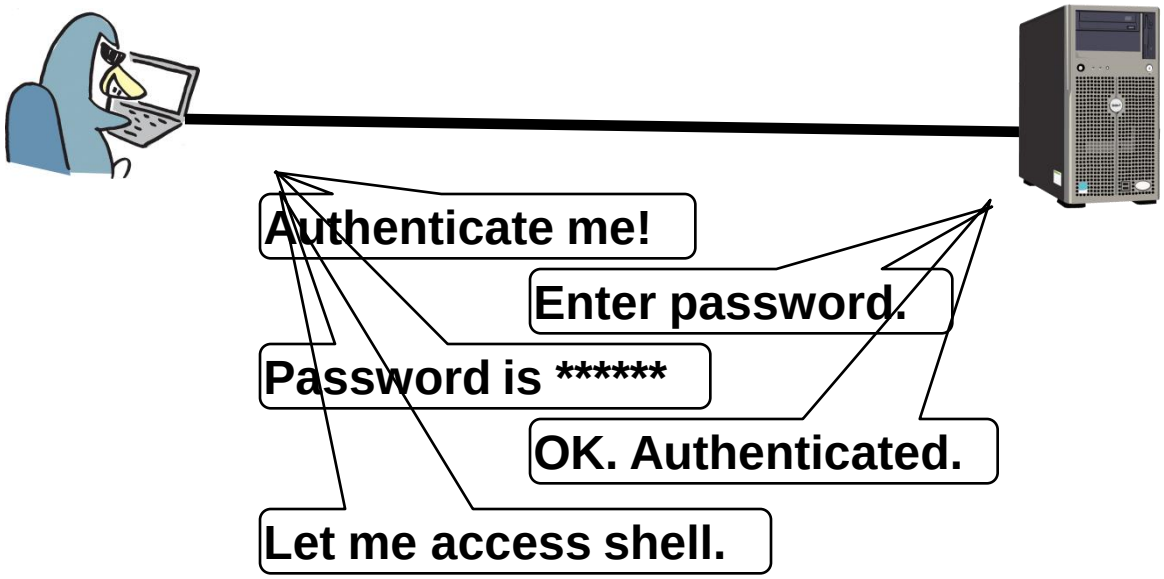
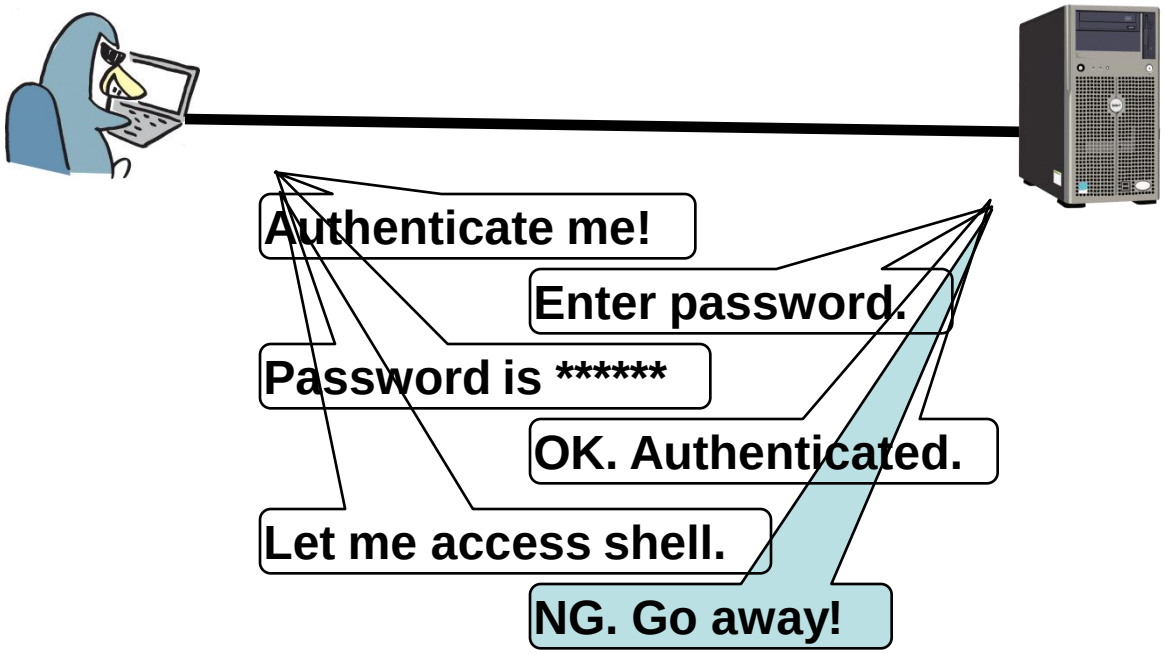


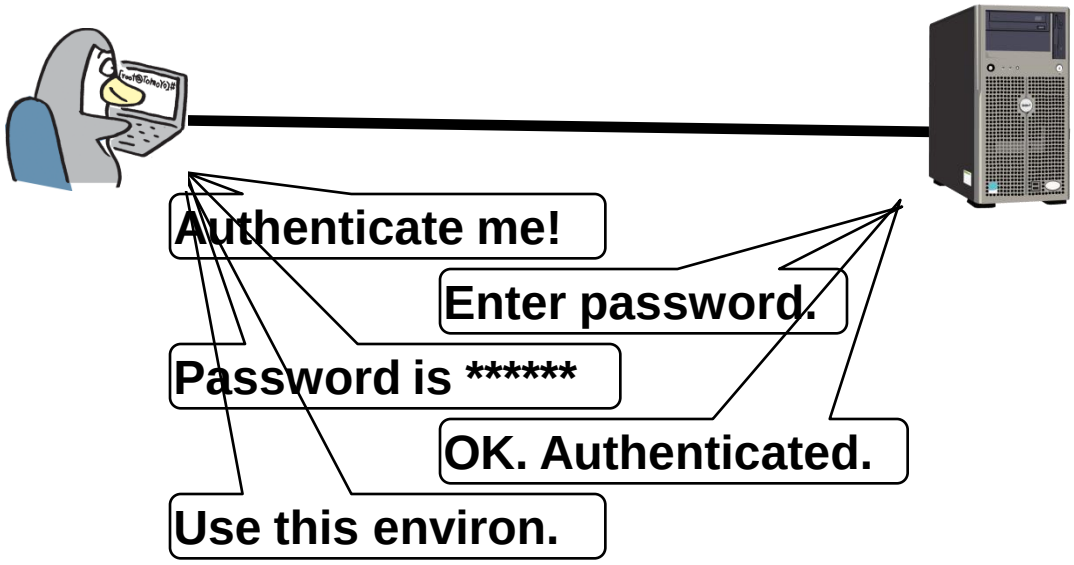
Case 3: Non-interactive shell session



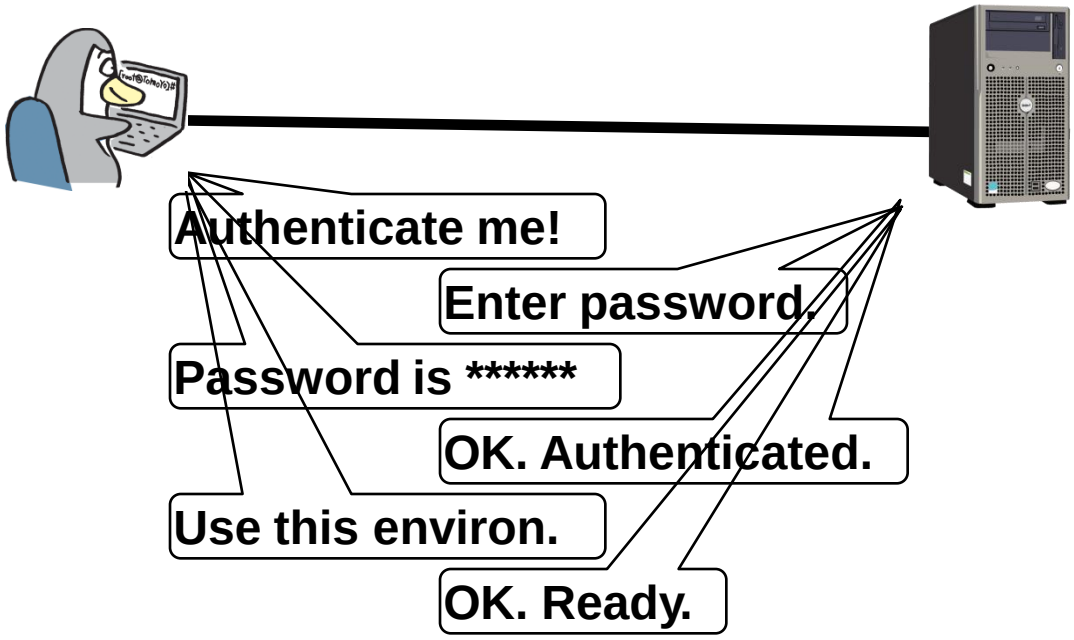
Case 3: Non-interactive shell session



Case 3: Non-interactive shell session



Case 3: Non-interactive shell session



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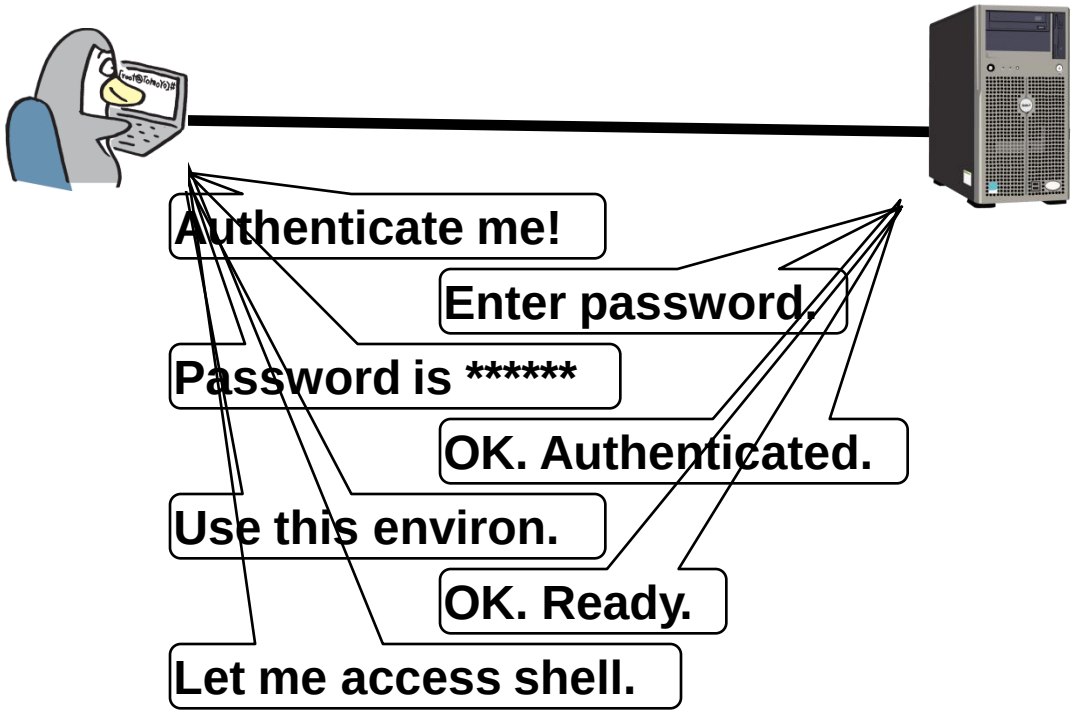
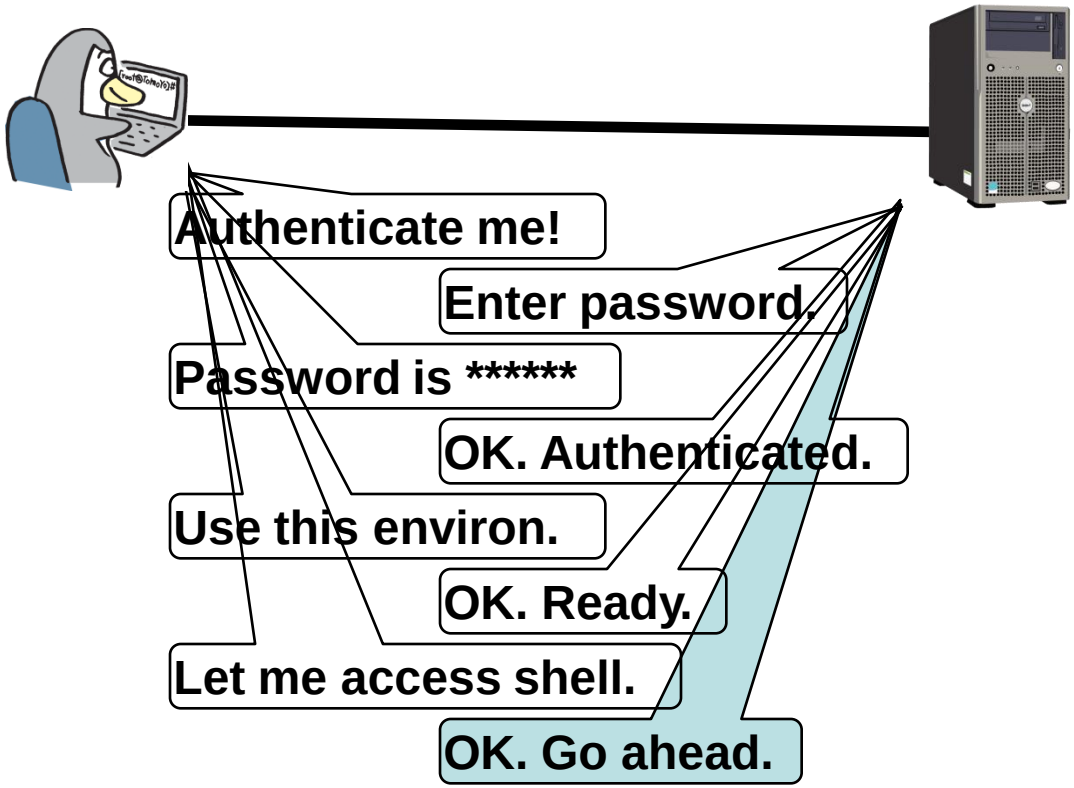


Case 3: Non-interactive shell session



Case 3: Non-interactive shell session

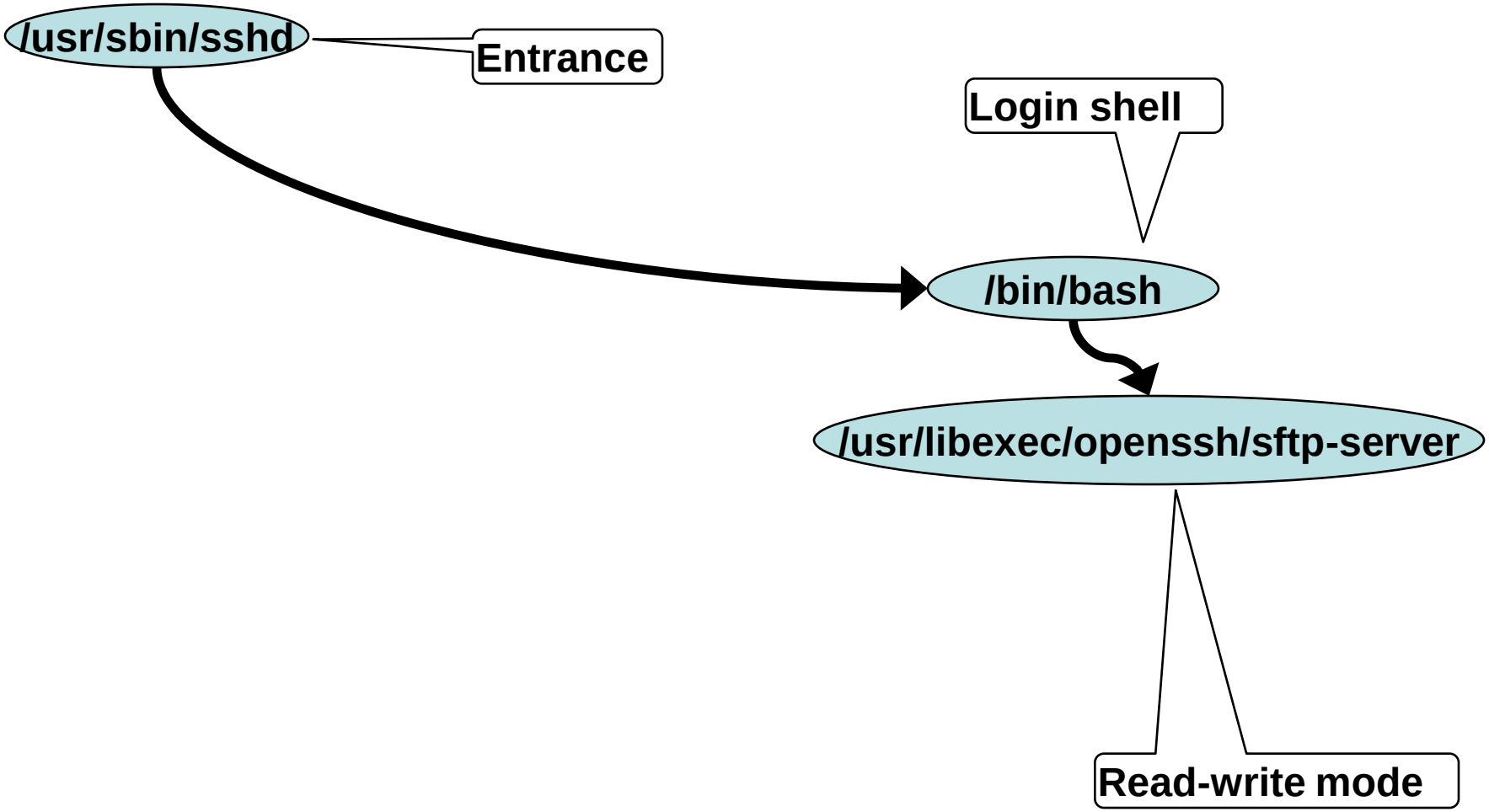
- Advantages
  - Transparent from client's point of view.
    - No need to modify command line.
    - No special handling for standard input/output.
  - You can use environment variables as password.
    - No need to disclose environment variable names.
    - You can assign different permissions according to the content of environment variables.
  - You can use this method for interactive shell session too.

Case 3: Non-interactive shell session

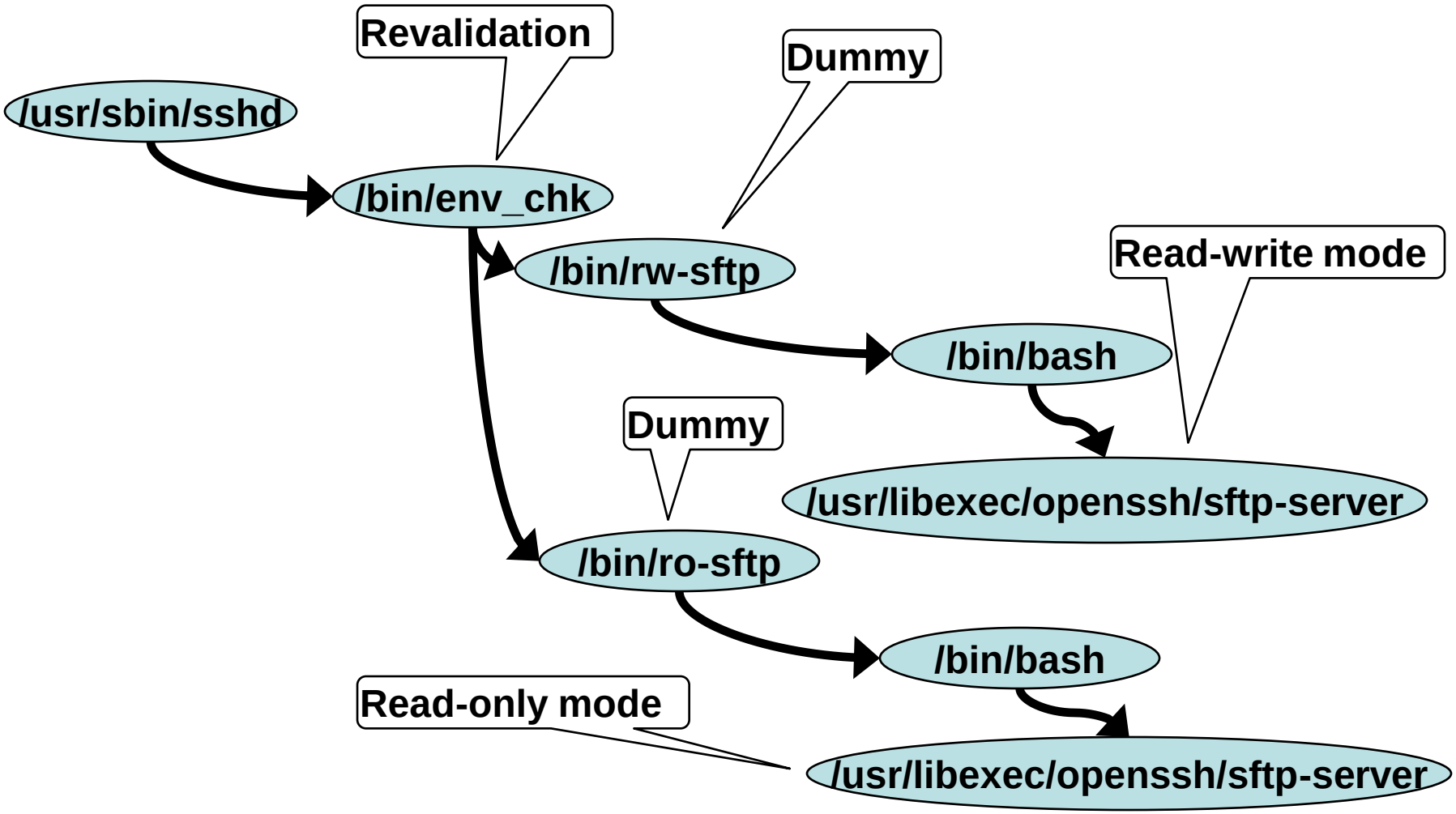
- Disadvantages
  - Available for only TOMOYO Linux.
    - I think only TOMOYO Linux supports execute_handler mechanism.
  - Possibility that a SSH client does not support SendEnv directive.

Case 3: Non-interactive shell session

- Example: Switch via environment variable.



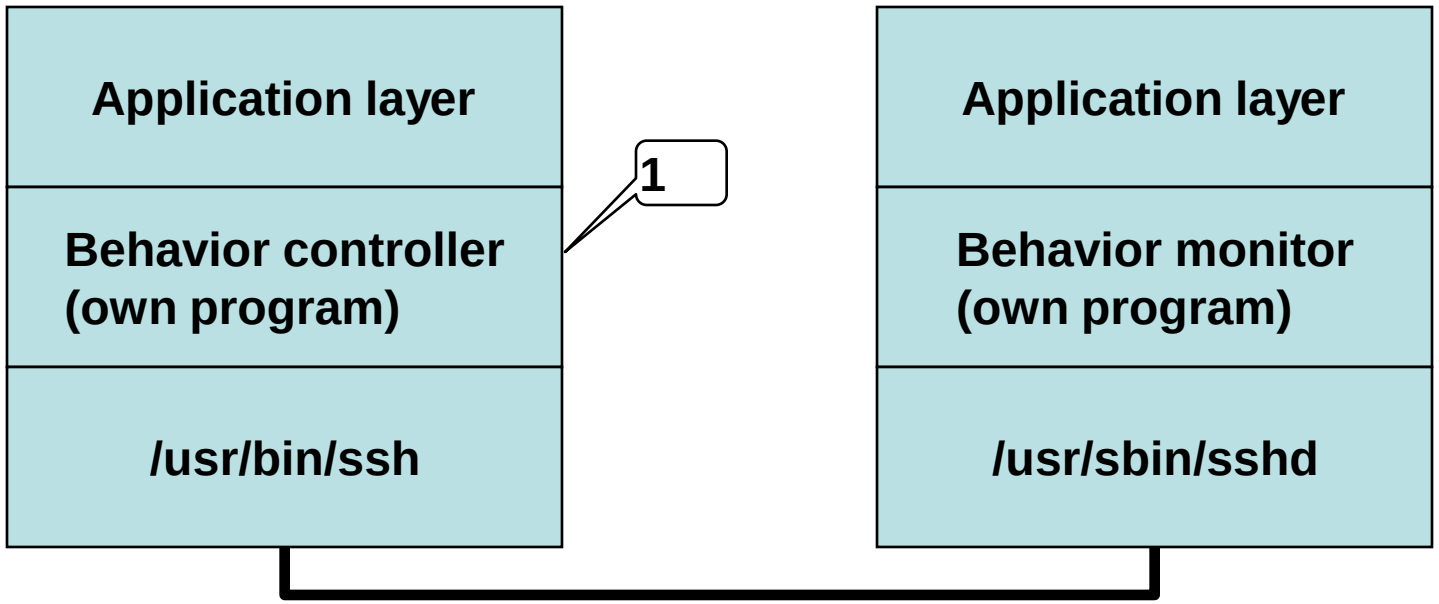
Case 3: Non-interactive shell session



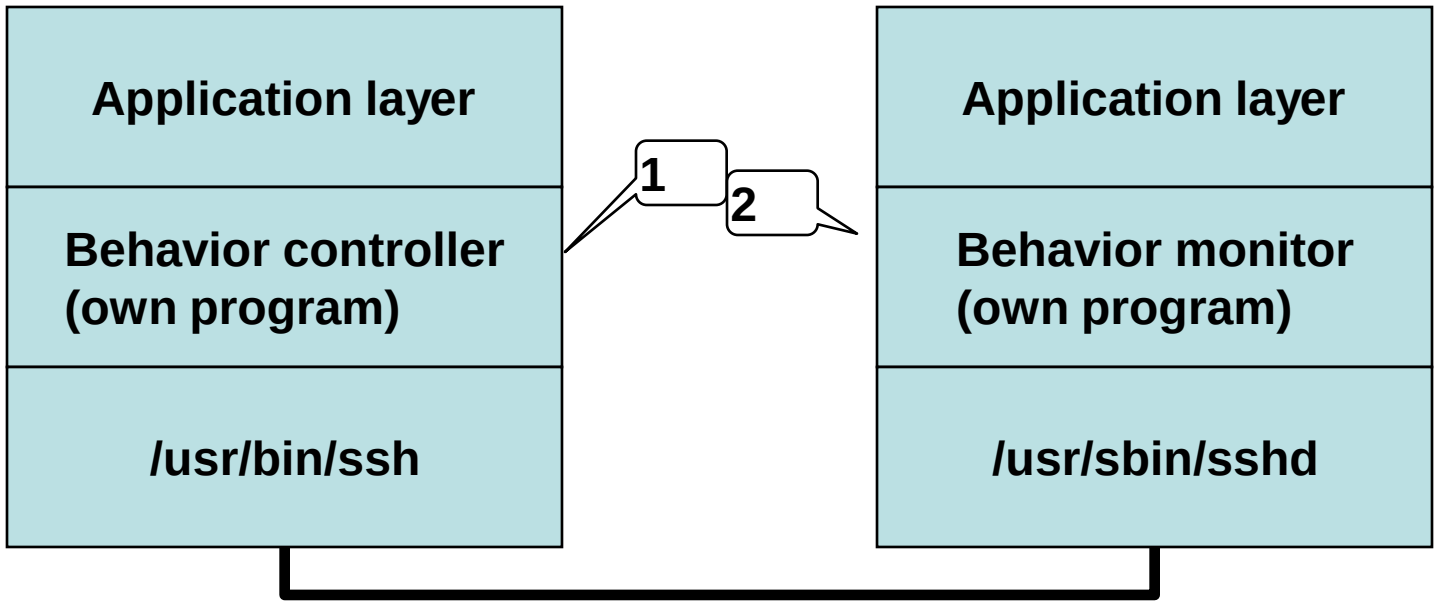
Case 4: Non-interactive shell session

- Introduce original layer.
  - What we need
    - "-S" option of scp and sftp commands.
    - A server side program for monitoring behavior.
    - A client side program for controlling behavior.
    - TOMOYO Linux's execute_handler directive.

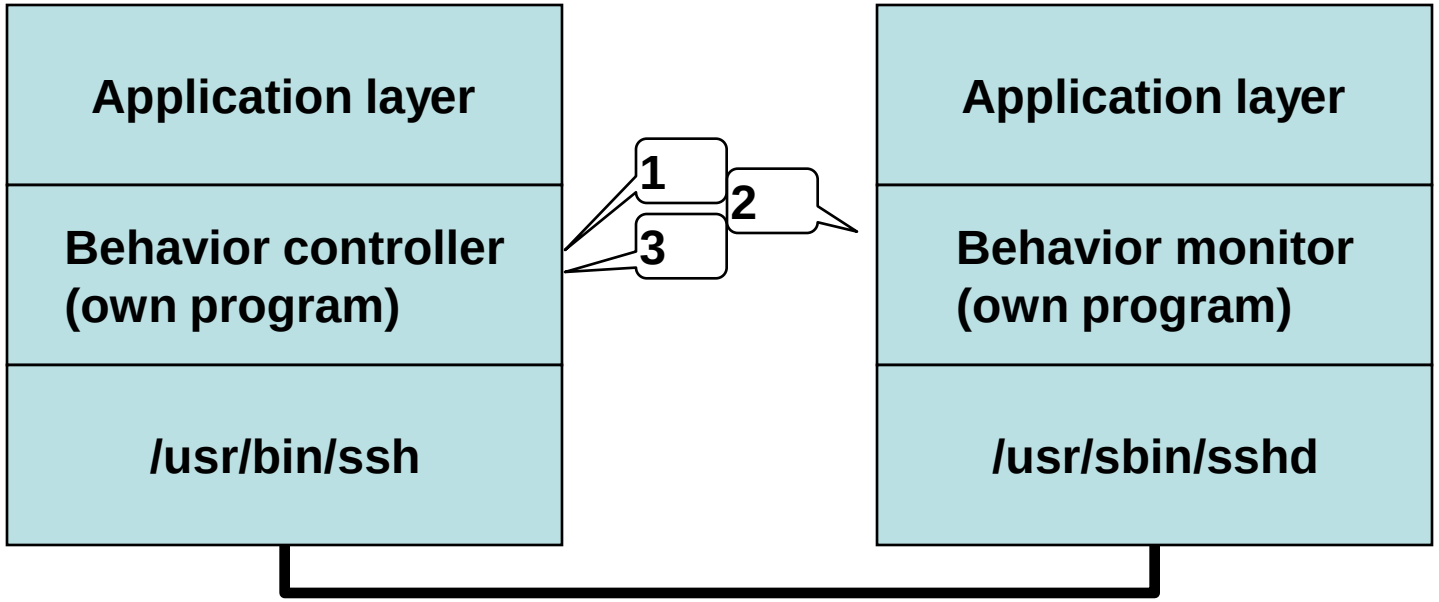
Case 4: Non-interactive shell session



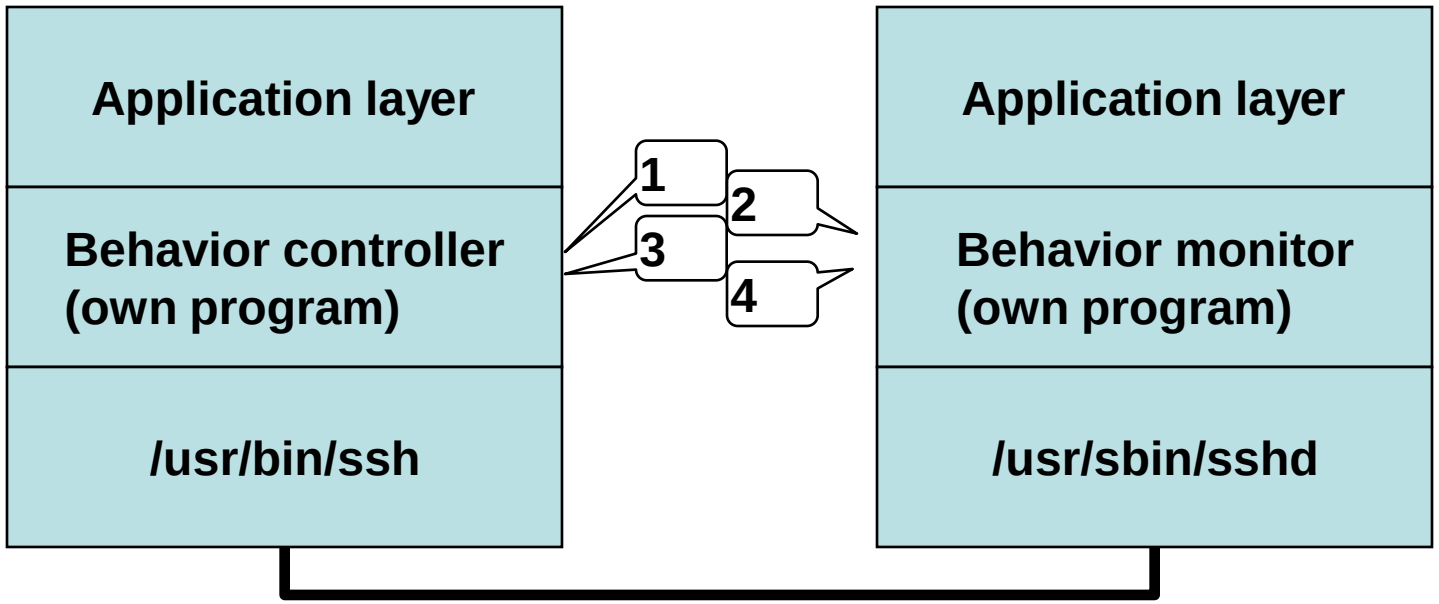
Case 4: Non-interactive shell session



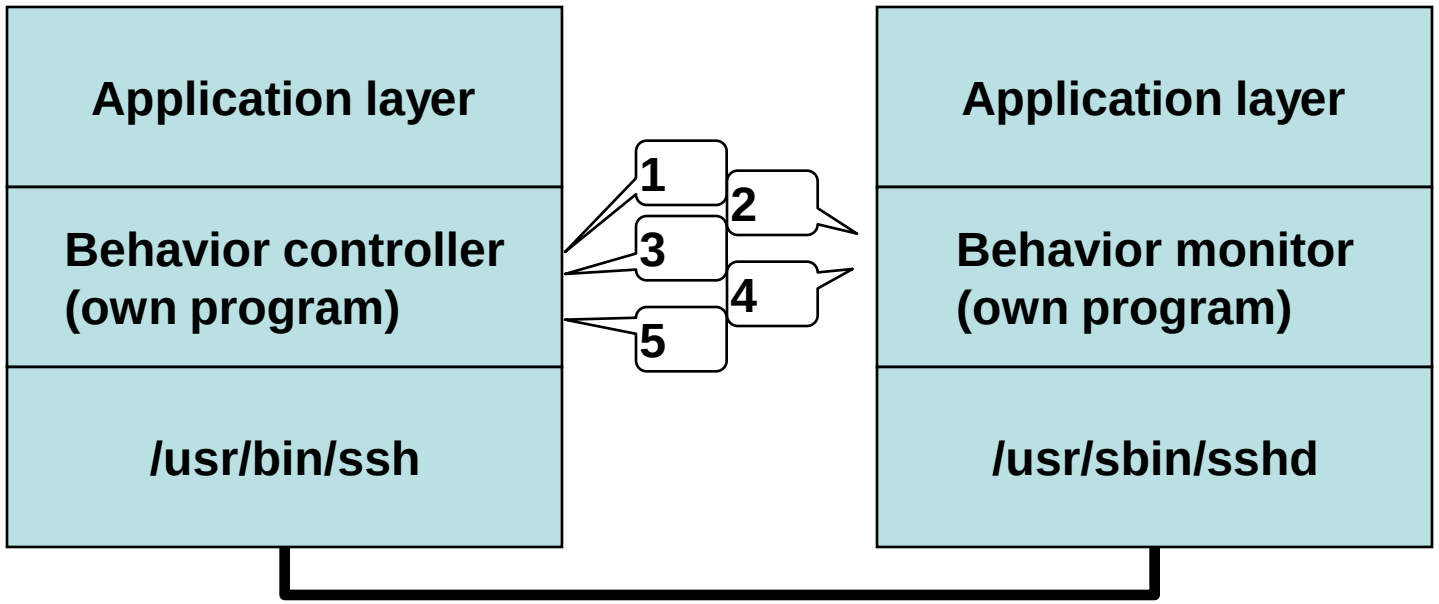
Case 4: Non-interactive shell session



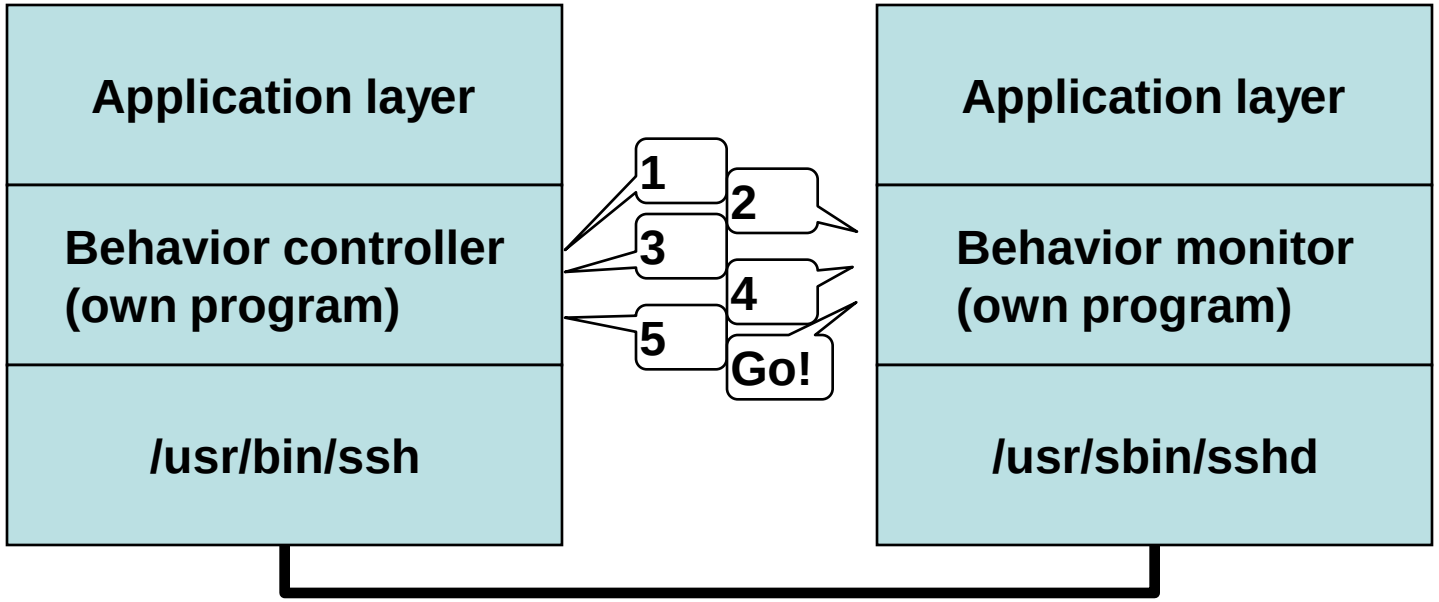
Case 4: Non-interactive shell session



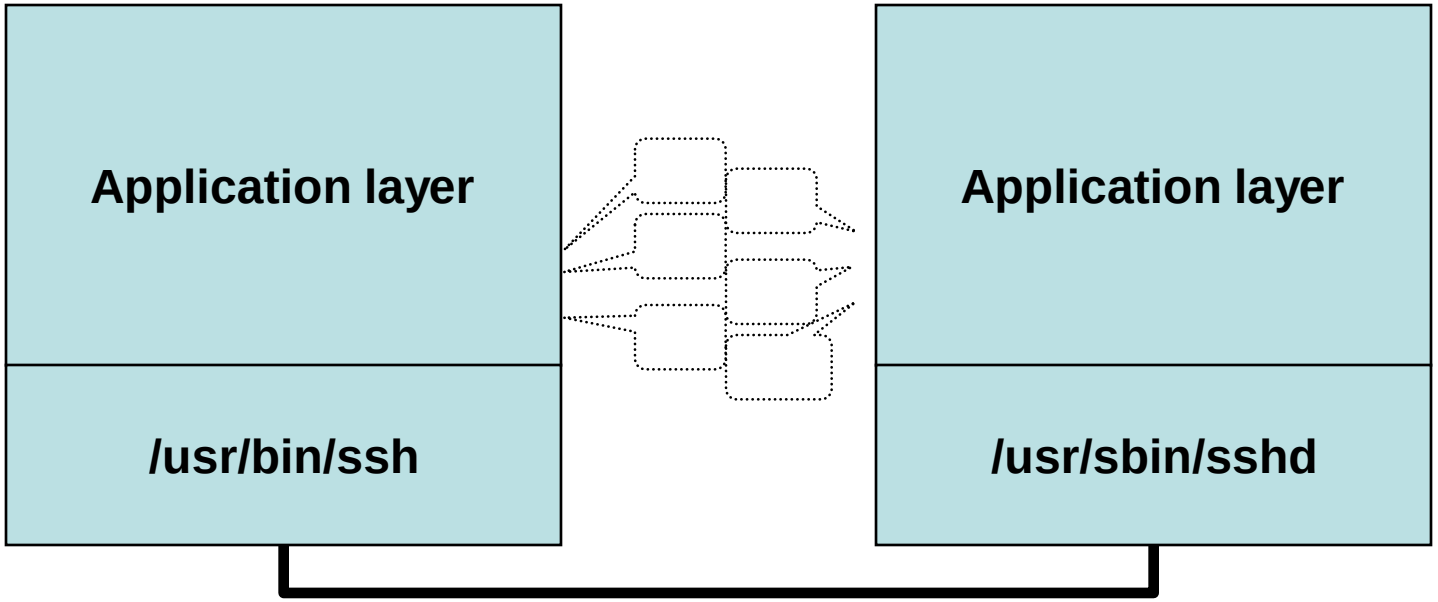
Case 4: Non-interactive shell session



Case 4: Non-interactive shell session



Case 4: Non-interactive shell session



Case 4: Non-interactive shell session

- Advantages
  - You can use factors which cannot be used by default (e.g. standard input/output, command line parameters).
  - You can combine this method with environment variables.
    - You can give more permissions to only clients which support this method.

Case 4: Non-interactive shell session

- Disadvantages
  - You need to prepare a client side program.

Why not implement using PAM?

- Degree of freedom and difficulty.
  - No interference with other PAM modules, for all factors (e.g. standard input/output, command line parameters) are dedicated to the own program.
- Everybody can develop their own programs.
  - Not restricted by standards like RFC.

Why not implement using PAM?

- No need to modify client programs.
  - PAM can’t be used unless the client supports it.
  - All clients can support programs executed after PAM (i.e. login shell).

Why not implement using PAM?

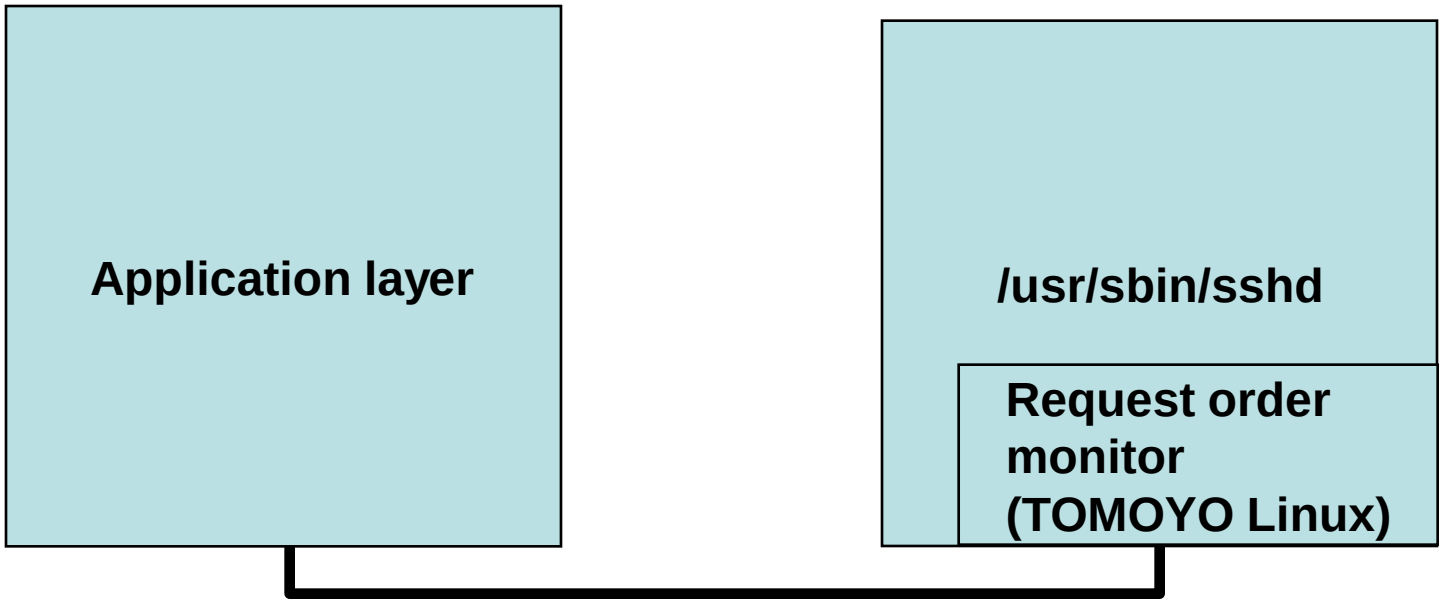
- You can make it mandatory.
  - No worry of being omitted by PAM configurations and/or other PAM module's results.
  - No worry of loopholes (e.g. buffer overflows, OS command injection from login shell) because all possible STD patterns are defined and enforced by MAC.
  - You can use external program's assistance casually.

All the best!

- You can use your original protocol because this approach is a local authentication.
  - Your idea shields yourself from attackers.
- There are infinite factors available.
  - Thus, brute force is impossible unless correct behavior (STD) is kept secret.
- You can implement low-cost and low-impact methods.

Case 5: Non shell session

- Customizing client program.
  - What we need
    - Original SSH client program (e.g. JSCH).
    - TOMOYO Linux's task.state keyword.



Case 5: Non shell session

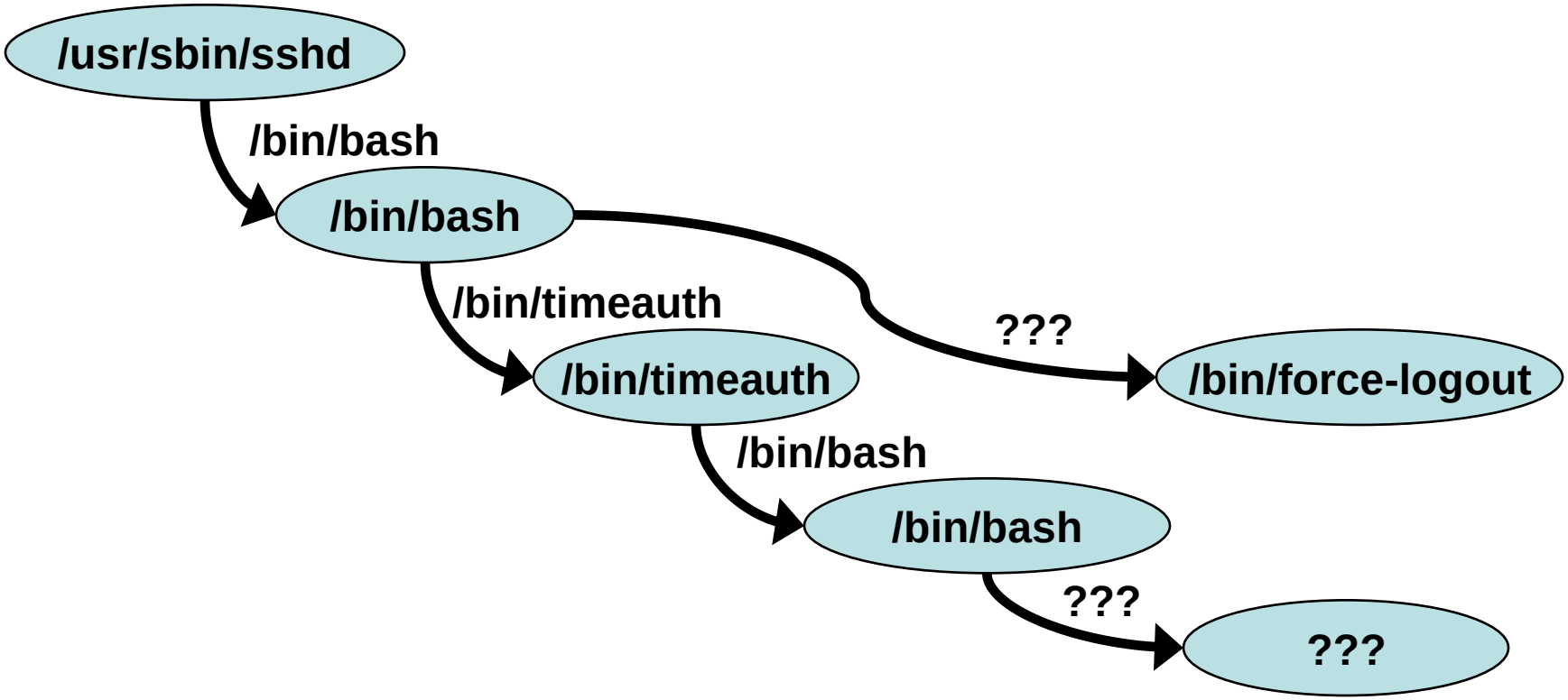
- Advantages
  - You can switch permissions without executing a program.
    - You can use the order of TCP port forwarding requests as password.
  - You can use this method for interactive and non-interactive shell sessions too.

Case 5: Non shell session

- Disadvantages
  - Available factors are limited.
    - You can’t rely on external program’s assistance.
  - Available for only TOMOYO Linux.
    - This method modifies TOMOYO Linux’s process state variables (i.e. task.state) without modifying the SSH server program (i.e. /usr/sbin/sshd).
  - You need to develop client program.

Case 6: Deploying on-demand honey pot

- You can redirect the intruder to honey pot.
  - Of course, you can forcibly logout.



A paper is available.

- Chained Enforceable Re-authentication Barrier Ensures Really Unbreakable Security
  - In short, CERBERUS, the gatekeeper.
  - http://sourceforge.jp/projects/tomoyo/docs/winf2005-en.pdf
  - The content may be obsolete because it was written 3 years ago.
  - But the concept will be useful and applicable even now.