National Institute of Advanced Industrial Science and Technology
AIST

RISEC
Research Institute for Secure Systems

Security on cloud storage and IaaS

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Overview of Security on IaaS Cloud Computing

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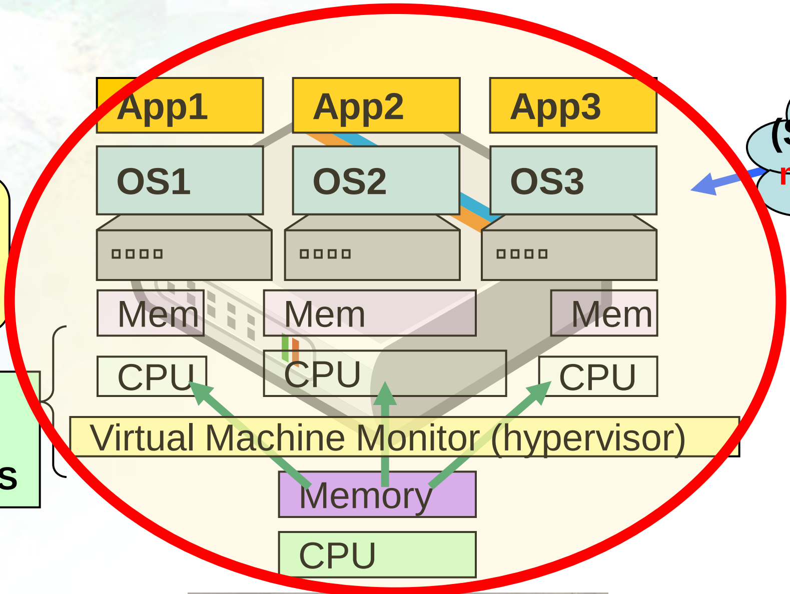


Internet
(Secure communication)
man in the middle attack

Formal Verification
To take high level EAL (Evaluation Assurance Level)

Software Vulnerability
- Hypervisor
- Management Host OS

Client User
- ID, Password, Secret Key management
- Software vulnerability Security update

Vulnerable (un-mature) safe

Security Guideline
- CSA (Cloud Security Alliance)
- Open Cloud Manifesto

Auditing Standard
- SAS70
- HIPAA

Data Management
- Information Leak
- Information Loss
- Information Erasure

Auditing
- Digital Forensic
- Log

My interests

- Sharing technologies (virtualization technologies) on IaaS are good for security?
  - Based on my papers [HotSec10], [EuroSec11], [EuroSec12]

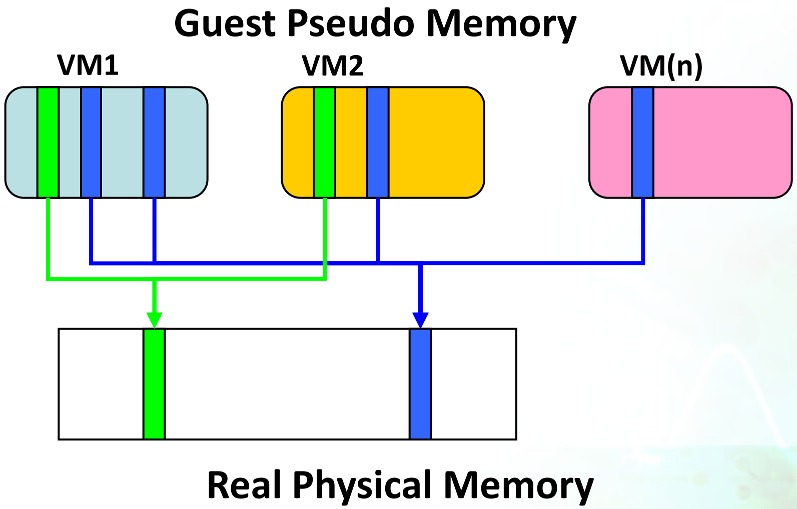
- Information leak / erase / loss on cloud storage
  - Funded by Strategic Information and Communications R&D Promotion Programme(SCOPE), Ministry of Internal Affairs and Communications (MIC).

Sharing Technology

- Sharing is a key technology on Cloud computing, because it can reduce costs. It offers pseudo physical devices and shares same parts of devices.
  - Virtual Machine
    - VMware, Xen, KVM, etc.
  - Storage deduplication
    - Dropbox, EMC products, etc.
  - Memory deduplication

Memory Deduplication

- Memory deduplication is a technique to share same contents page.
  - Mainly used for virtual machines.
  - Very effective when same guest OS runs on many virtual machines.
- Most memory deduplication are included in virtual machine monitors with different implementations.
  - VMware, Xen, and KVM have own memory deduplication



Is Memory Deduplication good or bad for security?

(1) Good

- From logical sharing to physical sharing [HotSec10]

(2) Bad

- Cross-VM Side Channel Attack [EuroSec11]
  - Cause Information leak

(3) Good or Bad

- Affects to current security functions (Address Space Layout Randomization, Memory Sanitization, Page Cache Flushing) [EuroSec11]

(1) Logical Sharing

- Current OSes use logical sharing technique to reduce consumption of memory.
  - “Dynamic-Link Shared Library”
- Unfortunately, it includes vulnerabilities caused by dynamic management.
  - Search Path Replacement Attack
  - GOT (Global Offset Table) overwrite attack
  - Dependency Hell
  - Etc.

(1) Solution, and further problem

- These vulnerabilities are solved by static-link in general, but it increase consumption of memory.
  - Fortunately, the increased consumption is mitigated by **memory deduplication** on IaaS.
  - It looks easy to solve the problem, but …
- Current applications assume dynamic-link and are not re-compiled as static-link easily.
  - Dynamic-link is used for avoiding license contamination problems. The programs includes “**dlopen()**” to call dynamic link explicitly.

(1) From Logical sharing to physical sharing

- Instead of static link, we proposed to use "*self-contained binary translator*" which integrates shared libraries into an ELF binary file. [HotSec'10]
  - The ELF binaries become fatter than static link, but the redundancy is shared by physical sharing (memory deduplication).

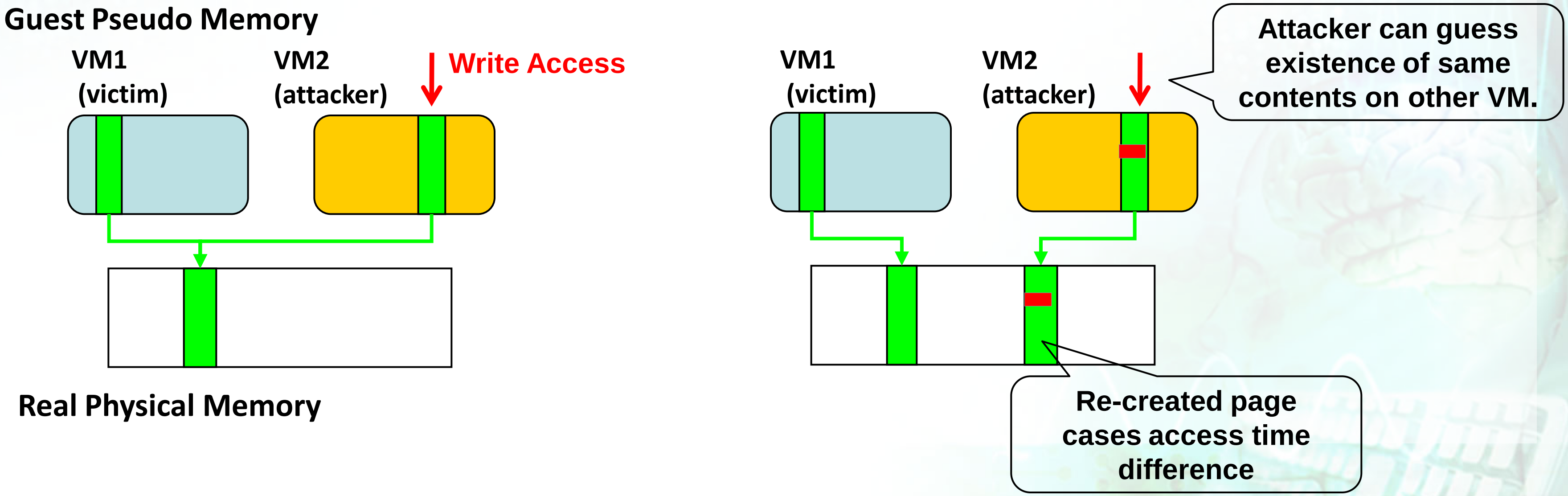
- OSes on a cloud can increase security.

(2) VM Side Channel Attack

- Memory deduplication is vulnerable for side channel attack.
  - The vulnerable is caused by Copy-On-Write of memory deduplication.
  - Copy-On-Write is a common technique to manage shared contents, but it became a Covert Channel for Information Leak.

(2) Copy-On-Write (COW)

- When a write access is issued to a deduplicated page, a same contents page is created and accepts write access. This action is logically valid, but …
- ***Write access time difference*** between deduplicated and non-deduplicated pages due to copying.



Attacker can guess existence of same contents on other VM.

Re-created page cases access time difference

(2) Attacking problem

- Cross VM side channel attack looks simple, but there are some problems.

  ① 4KB Alignment problem

  - Attacker must prepare exact same pages in order to guess victim’s contents.

  ② Self-reflection problem

  - Caused by redundant memory management on cache and heap. Attacker has a false-positive result.

  ③ Run time modification problem

  - Caused by swap-out, etc. Attacker has a false-negative result.

- The attacking methods and countermeasure are mentioned in [EuroSec11].

(3) Affects of OS Security functions on memory deduplication

- Modern OSes have security functions that modify memory contents dynamically.
  1. Address Space Layout Randomization (ASLR)
  2. Memory Sanitization
     - Pages are zero-cleared. Increase deduplication.
  3. Page Cache Flushing
     - Useful to remove redundant pages.
- These security functions are affected by memory deduplication.

(3) Affects on Security Functions

- ASLR looks to be independent of memory deduplication because the contents are not changed on memory. However it increased consumption of memory, because It made different page tables.
- Memory Sanitization and Page Cache Flushing increase zero-cleared pages and help memory deduplication. However, the costs are heavy and they decreased performance severely.

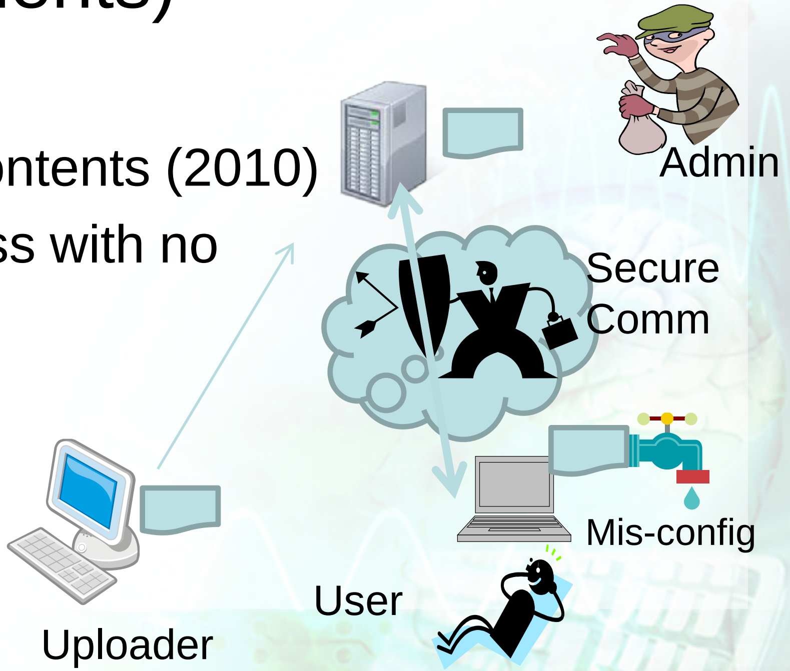
The detail is written in my paper [EuroSec'12]

Summary: OS on sharing technology

- Memory deduplication on cloud computing have a potential to change the structure of OS from the view of secuirty.
  - It will differ from OSes on devices (PC, Smartphone, etc), because OSes interact each other on IaaS.
- The OS on IaaS should take care of security and performance on the environment which shares resources with others.

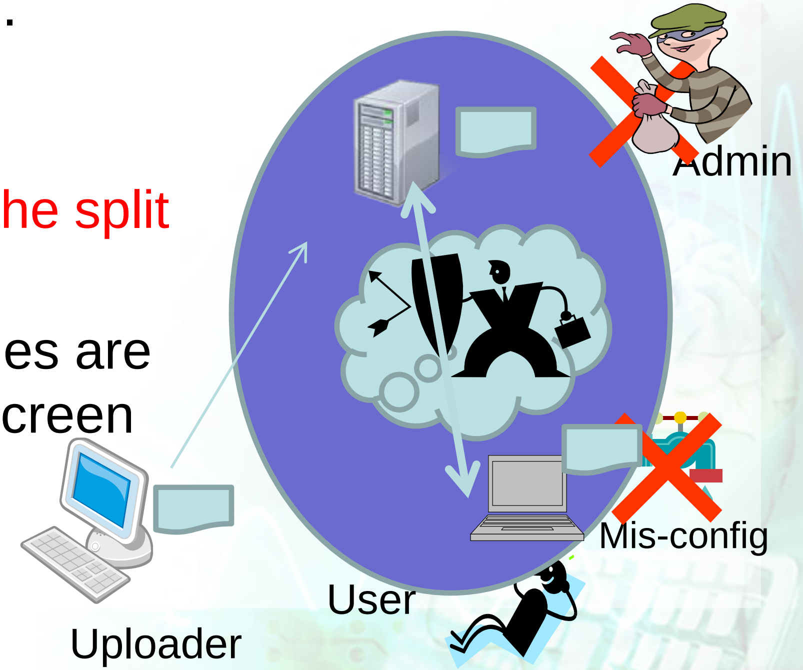
Data management Problem Information Leak

- Information leak does not occur on network.
  - Secure communication (ssh, SSL/TLS, etc) is established between client and server, and it is not easy to attack.
- Most information leaks on cloud storage occur on both edge machines (servers and clients)
  - On server
    - Gmail Administrator read use's contents (2010)
    - Dropbox had a bug to allow access with no pass word (2011)
  - On Client
    - P2P File sharing
    - (Japanese "Winny") (2003 ~)

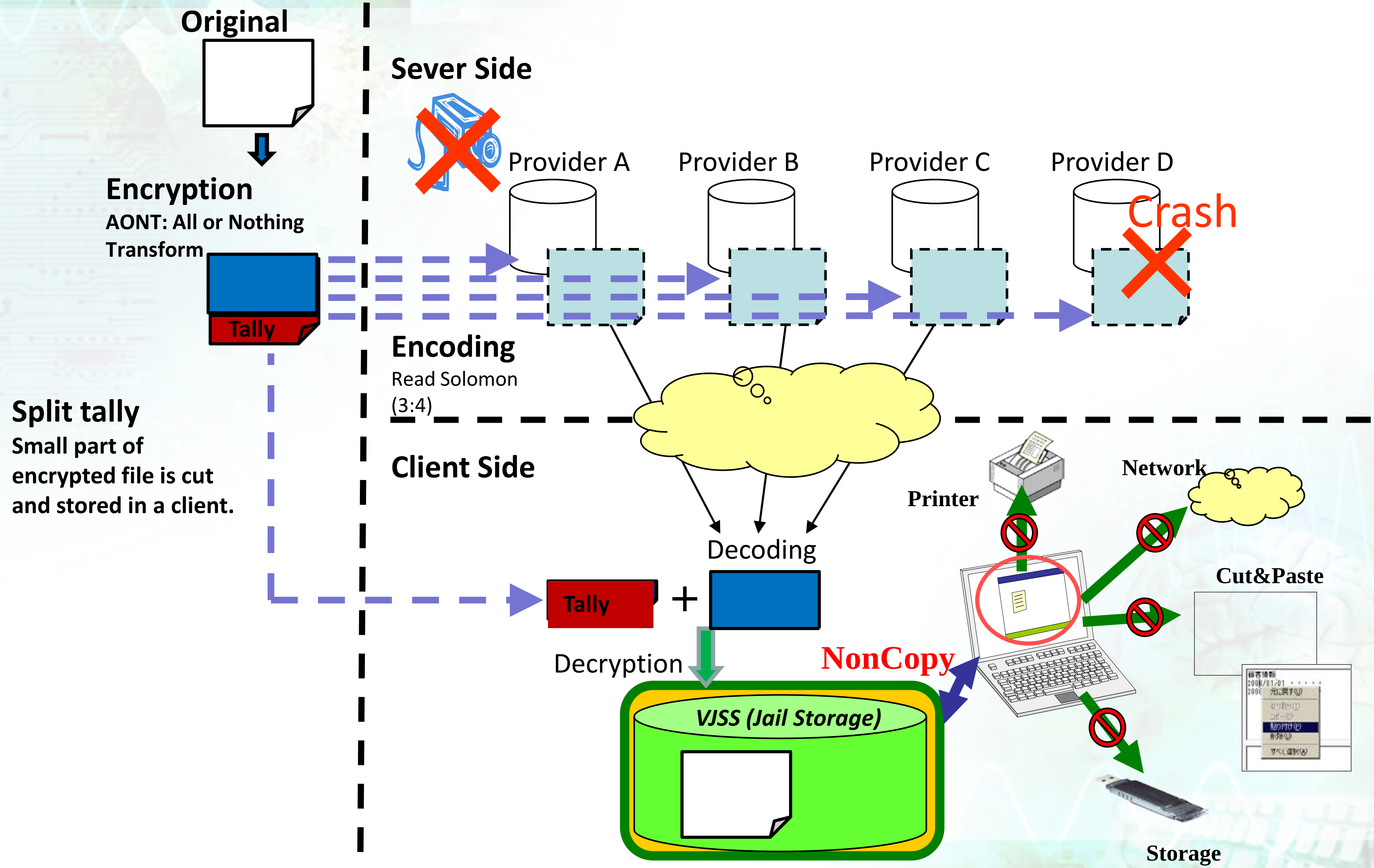


Our proposal

- Virtual Jail Storage System (VJSS)
  - On Server:
    - Data are encrypted and cut a split tally.
    - It mean that whole content of file are not upload. Even if the all uploaded data are gathered, the full contents are not reconstructed.
    - Data are also coded by Reed-Solomon and uploaded on some servers. It works for fault tolerance.
  - On Client:
    - Original file is reconstructed with the split tally.
    - Files are under access-control. Files are prohibited copying, printing, and screen cut&paste.



Overview of VJSS



Original

Encryption

AONT: All or Nothing Transform

Tally

Split tally

Small part of encrypted file is cut and stored in a client.

Sever Side

Provider A

Provider B

Provider C

Provider D

Crash

Encoding

Read Solomon (3:4)

Client Side

Decoding

Tally +

Decryption

NonCopy

VJSS (Jail Storage)

Printer

Network

Cut&Paste

Storage

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Deploying Plan (Against Disaster)

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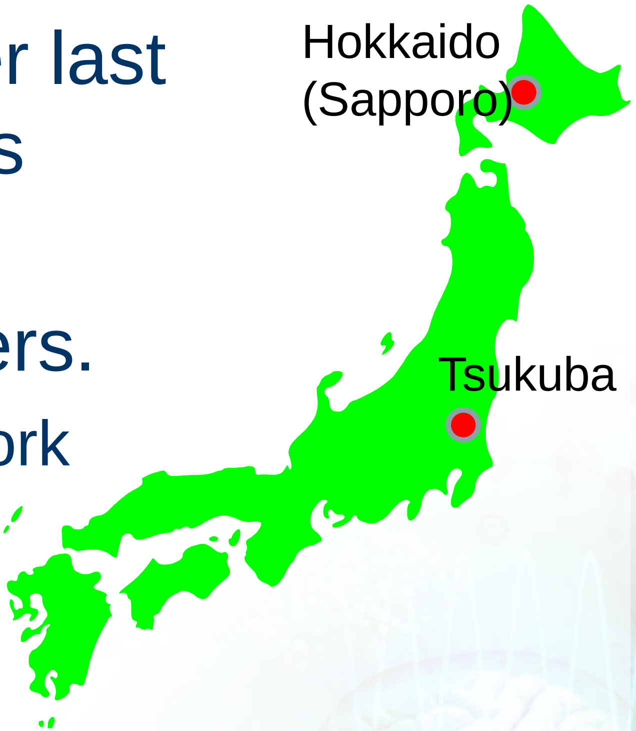
- Japan had a heavy natural disaster last year. The deploying plan considers location against disaster.
- Collaborate with Japanese providers.
  - Hokkaido Telecommunication Network
    - Tokyo - Hokkaido(Sapporo) 1,000km
  - Dream Arts Okinawa
    - Tokyo - Okinawa 1,500km
- Severs for VJSS will be located at the southern and northern edges of Japan in order to prevent natural disasters.



Okinawa
Taiwan

Information Erase (Planned)

- Most users want to erase uploaded data completely, after the service is terminated.
- Unfortunately most provider cannot guarantee that all uploaded data are removed.
  - Even if uploaded data are encrypted, the data may be decrypted by brute-force attack.
- Our VJSS is a little bit advanced, because it keeps split tally in a client. Even if all uploaded data are decrypted, all contents are not disclosed.

Information loss (Planned)

- Hosting services have to prevent data loss, but some incidents occurred.
    - T-Mobile Sidekick lost user’s data (2009).
    - Japanese provider FirstServer lost user’s data (2012).
- Most information loss incidents were caused by operation mistake.
- VJSS has data redundancy by Reed-Solomon error correction, but it is not enough.
- We propose to use append-only file system on Cloud Storage.
    - Most data will be shared by deduplication technology.

Conclusion

- Sharing technology (deduplication) on IaaS has a potential to change the structure of OS on it.
- Many people want to use cloud storage, but they are afraid of information leak/erase/loss.
  - Virtual Jail Storage System (VJSS) prevents information leak from a server and a client. VJSS plans to treat information erase and loss.