ITU Workshop on Quantum Information Technology (QIT) for Networks
(Shanghai, China, 5-7 June 2019)
Session 3C: QKD networks

Tokyo QKD Network

and its application to distributed storage network

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and Communications Technology (NICT)

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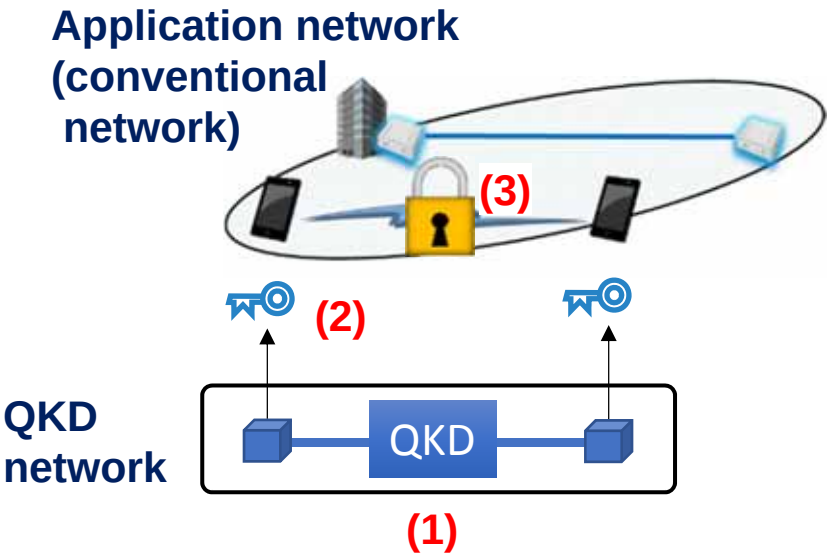
Quantum Key Distribution

- New add-on security service by providing cryptographic keys to the conventional communication network
- QKD keys provide “information-theoretic security (IT-sec)”
  -> unbreakable by *any* computational decryption attack (even with quantum computers)

<Conventional network and QKD network>



(1) QKD network shares IT-sec keys between distant parties

(2) IT-sec Keys are provided to applications

(3) Data is protected by the ITS keys

Basic features of QKD

- It protects security of data transmission
- It works in a point-to-point link, not in a multi-party link
- Speed and distance of a direct link are limited

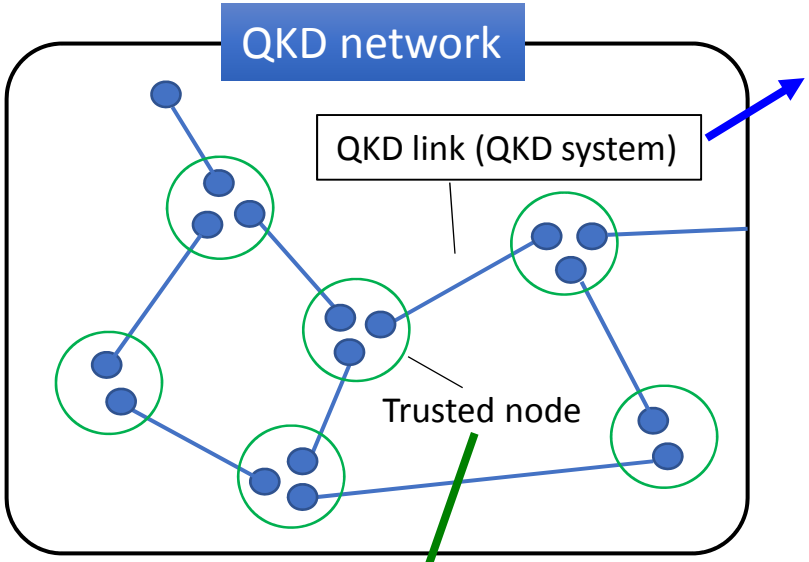
  1M bits/s at 50km (Movie data, e.g. MPEG4)
  10k bits/s at 100km (Voice data)
  (for standard optical fiber with loss rate of 0.2dB/km)

- Networking is made by introducing the trusted nodes,
  and by relaying a key via the nodes

- QKD is vulnerable to Denial of Service attack.
  A rerouting mechanism over a network is essential.

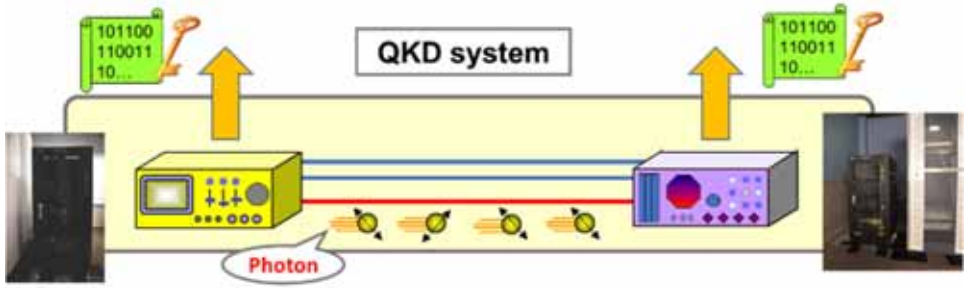
QKD network (current)

consists of point-to-point QKD links and trusted nodes

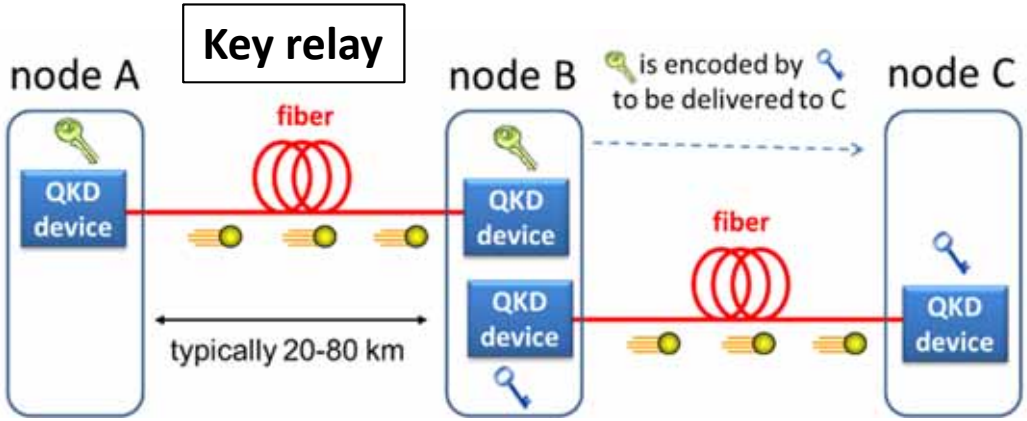


QKD link: deliver IT-sec keys p-to-p

Consists of quantum channel (sending photons) and classical channels (sync. & key distillation)



Trusted node: protected node to relay IT-sec keys



Why networking?

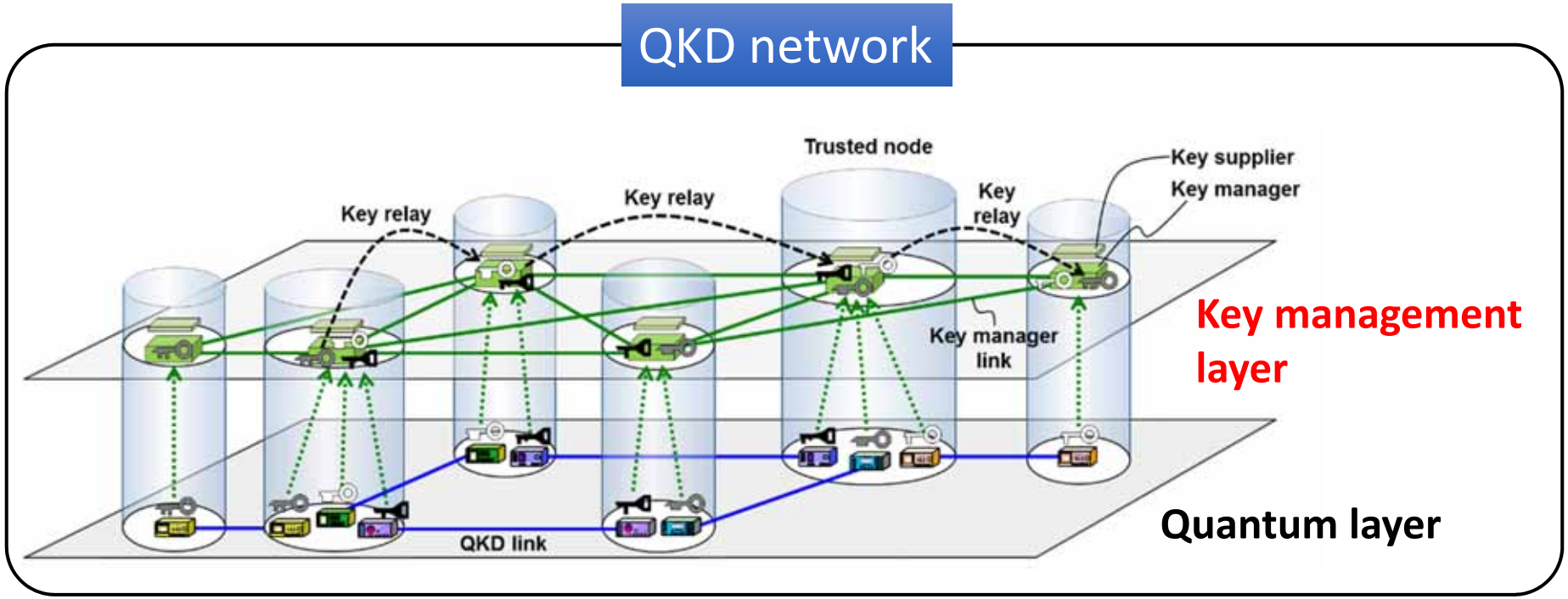
1. P-to-P QKD link distance is fundamentally limited by the photon loss (usually < 100km)

2. Network redundancy for stable operation (rerouting)

Key (relay) management

- QKD network should have a key management layer (KML)

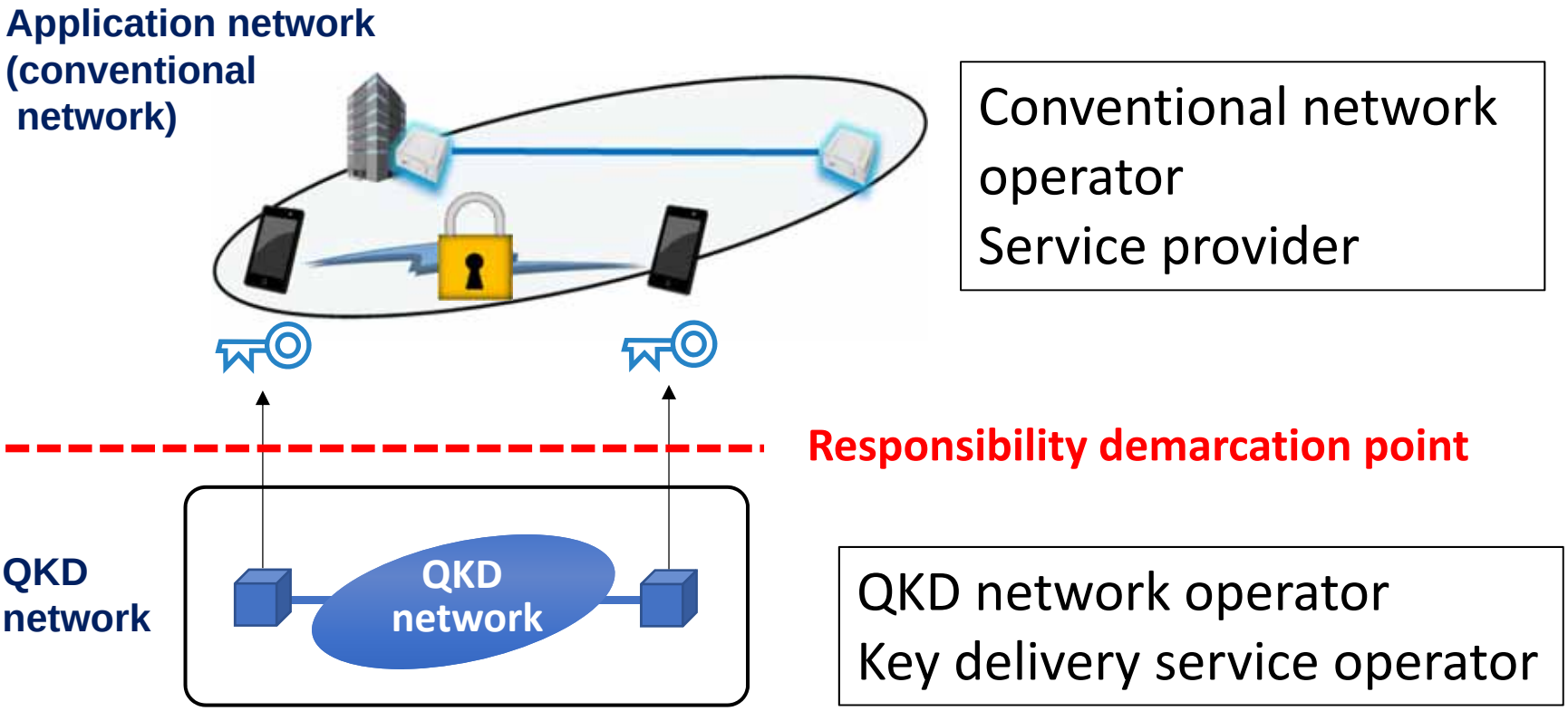
  KML: logical links (not quantum channels) managing the key relay and key supply to the conventional network (applications)



The QKD operator is responsible for the secure operation of both the KML and the quantum layer

QKD operation/security demarcation

- It is important to clarify the security responsibility demarcation between the conventional network and the QKD network



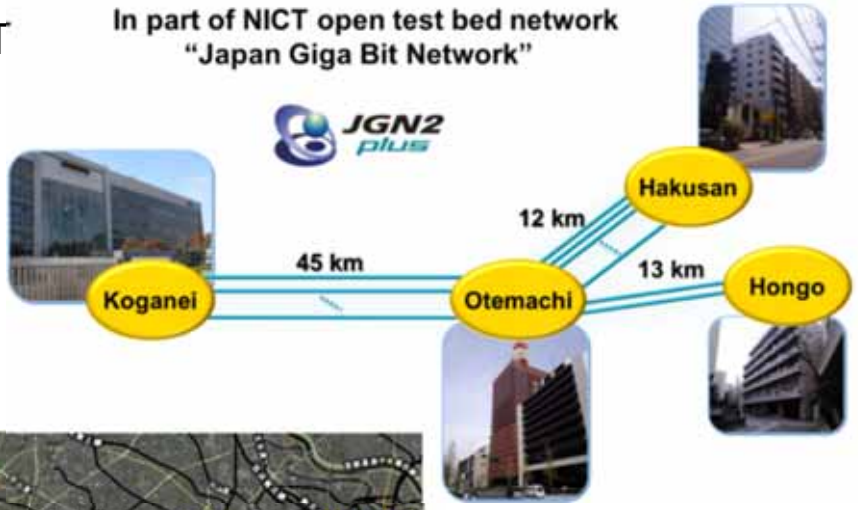
Tokyo QKD Network

Tokyo QKD Network

- QKD field testbed network on JGN-X in Tokyo, Japan

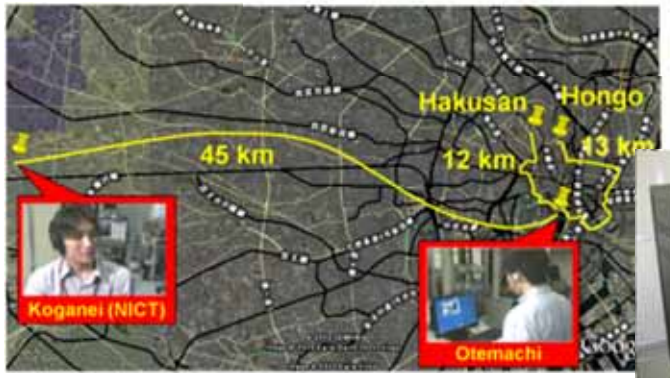
  - QKD links are connected via the trusted nodes
  - JGN: open testbed fiber network provided by NICT

M. Sasaki et al.,
Opt. Express 19, 10387 (2011)



- Constructed in 2010
  (World first TV conf. demonstration
  at UQCC2010)

- 4 companies
  (NEC, Toshiba, MELCO, NTT),
  8 universities,
  2 national institutes



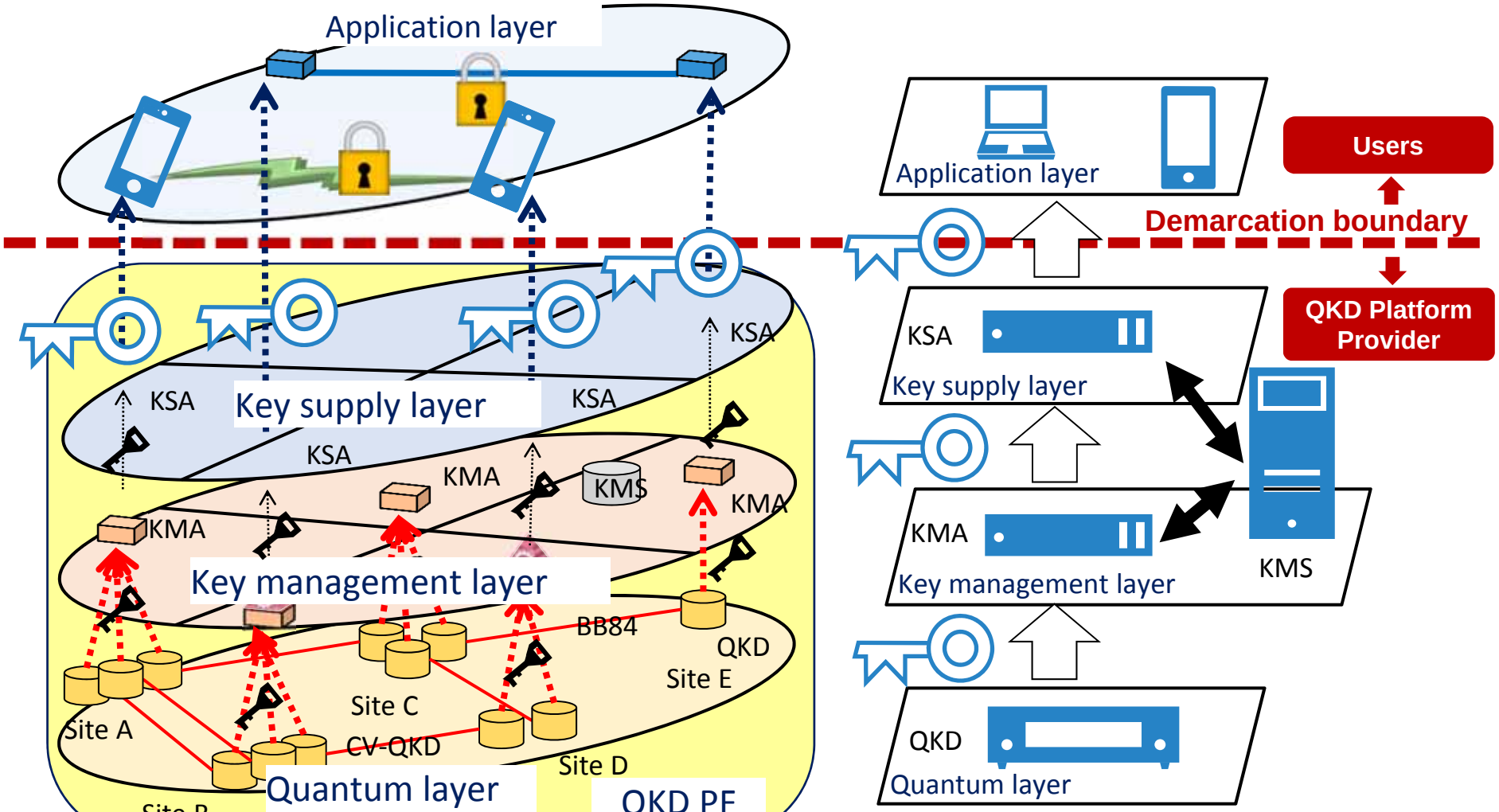
QKD sender and receiver (NEC, 2017)

- Continuously operated for
  long-term field tests, network
  experiments, and application
  developments

http://www.uqcc.org/ http://www.tokyoqkd.jp/

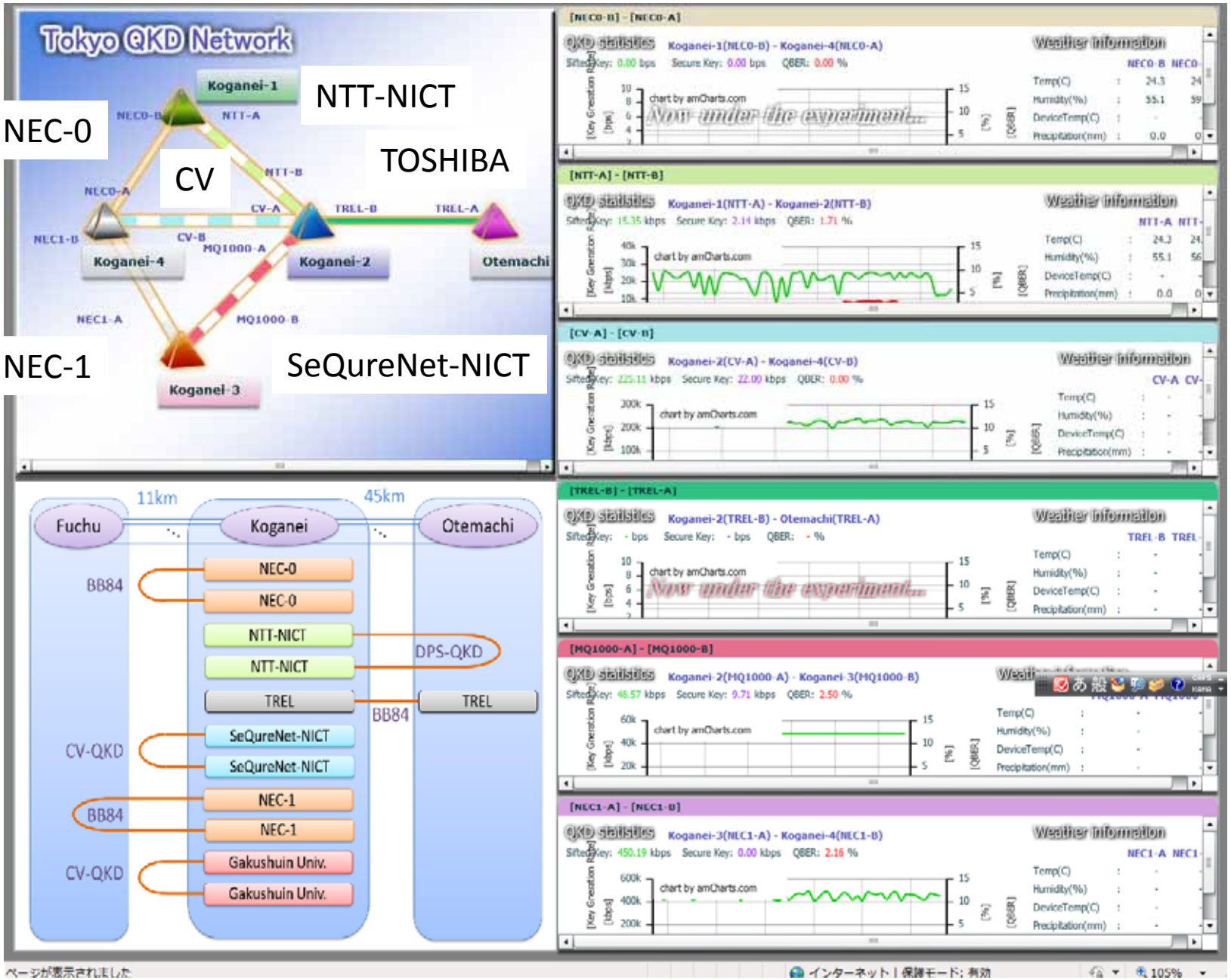
Tokyo QKD Network Architecture

- ✓ **A demarcation boundary between a QKD platform provider (an ITS key provider) and users should be clearly defined.**



KSA: Key supply agent
KMA: Key management agent
KMS: Key management server

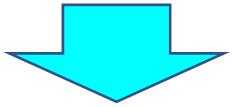
http://www.tokyoqkd.jp/



Application
(LINCOS)

Security lifetime

- QKD keys provide "information-theoretic security (IT-sec)"
  -> unbreakable by *any* computational decryption attack

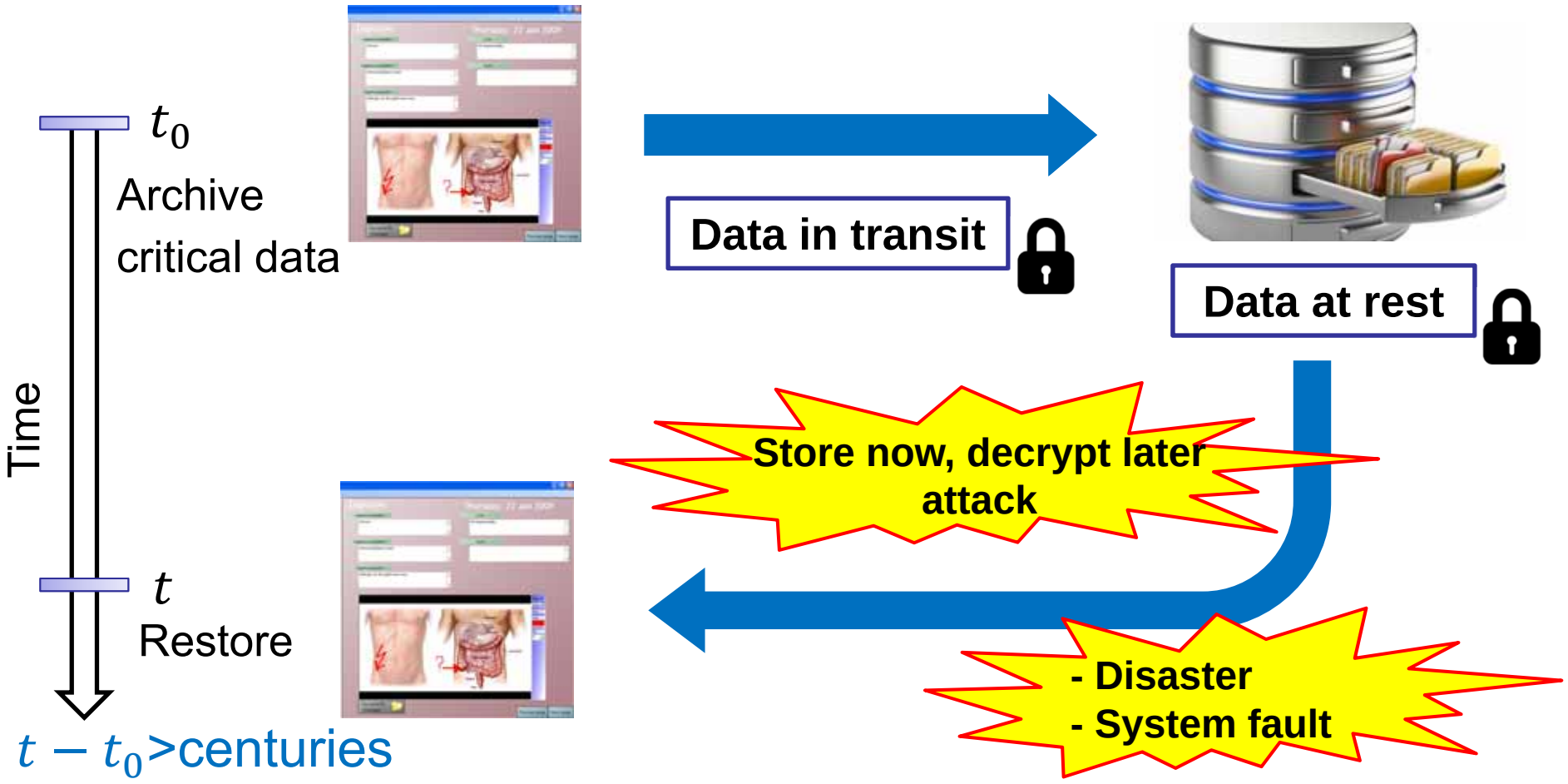


Long-term security

⇔ computational security for public key cryptos

→ Risk that it will be broken
by *future* computing/algorithm technologies

Long-term security



(1) Confidentiality

No information leak on the data in transit and at rest.

(2) Integrity

The data existed at time t_0 and has not been changed since.

Requirements for long-term security system

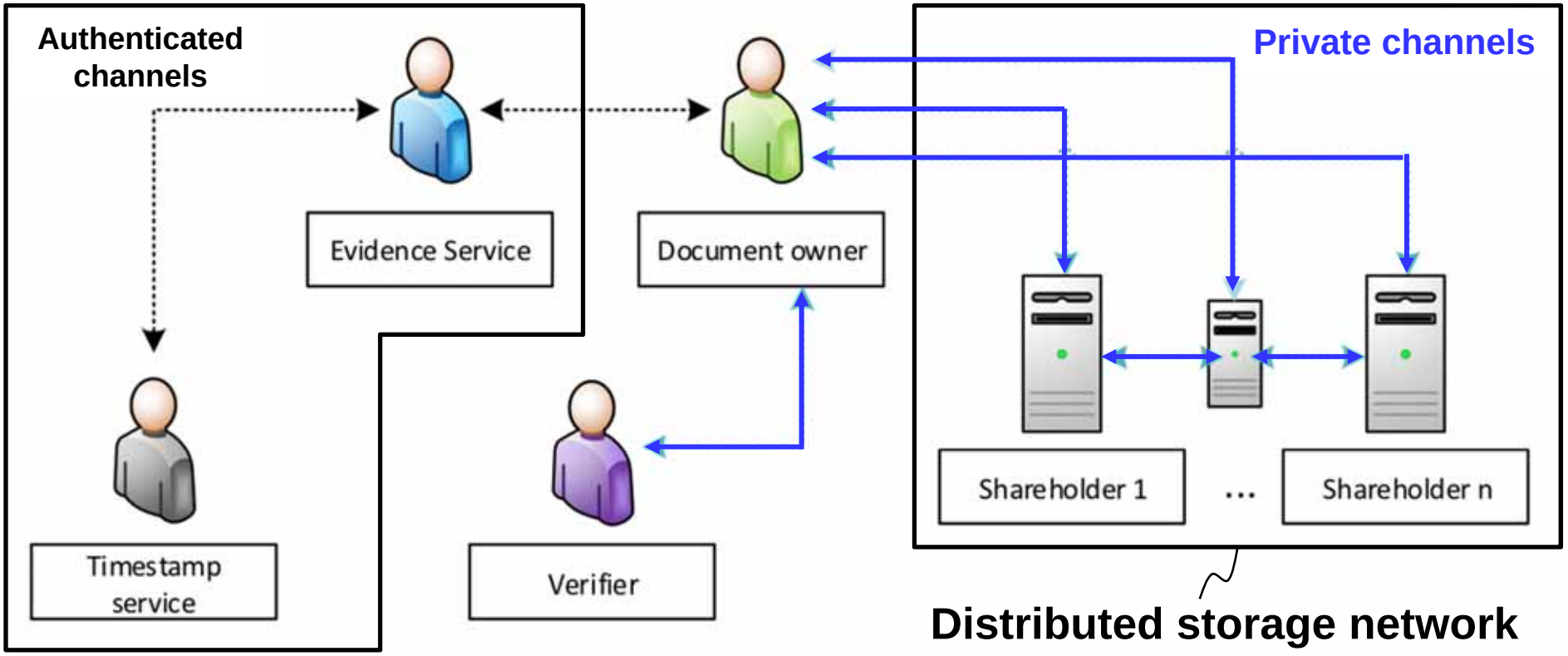
Requirement	Meaning	Solution
(i) Confidentiality	The data should be accessible only to authorized parties.	- **Information theoretically secure** storage and communication - Secure **access control**
(ii) Integrity	The data should remain unaltered.	Signature and authentication with **prolongable validity**
(iii) Availability	The data should be available whenever required.	**Redundant** data backup
(iv) Functionality	The data can be processed without decryption.	(Fully) **homomorphic** encryption

So far, partial solutions have been developed and used,
i.e., long-term confidentiality only, or long-term integrity only.
However,
no comprehensive solution has been demonstrated yet.

Long-term integrity, authenticity, and confidentiality protection system "LINCOS"

TU Darmstadt - NICT,

J. Braun et al., Proc. ACM Asia CCS2017, pp. 461-468.; ePrint 2016/742



Basic components for LINCOS

1. Information theoretic confidentiality of storage
3. Availability (redundant data backup)
4. Functionality (Multi-party secret computing)

(1) Secret sharing

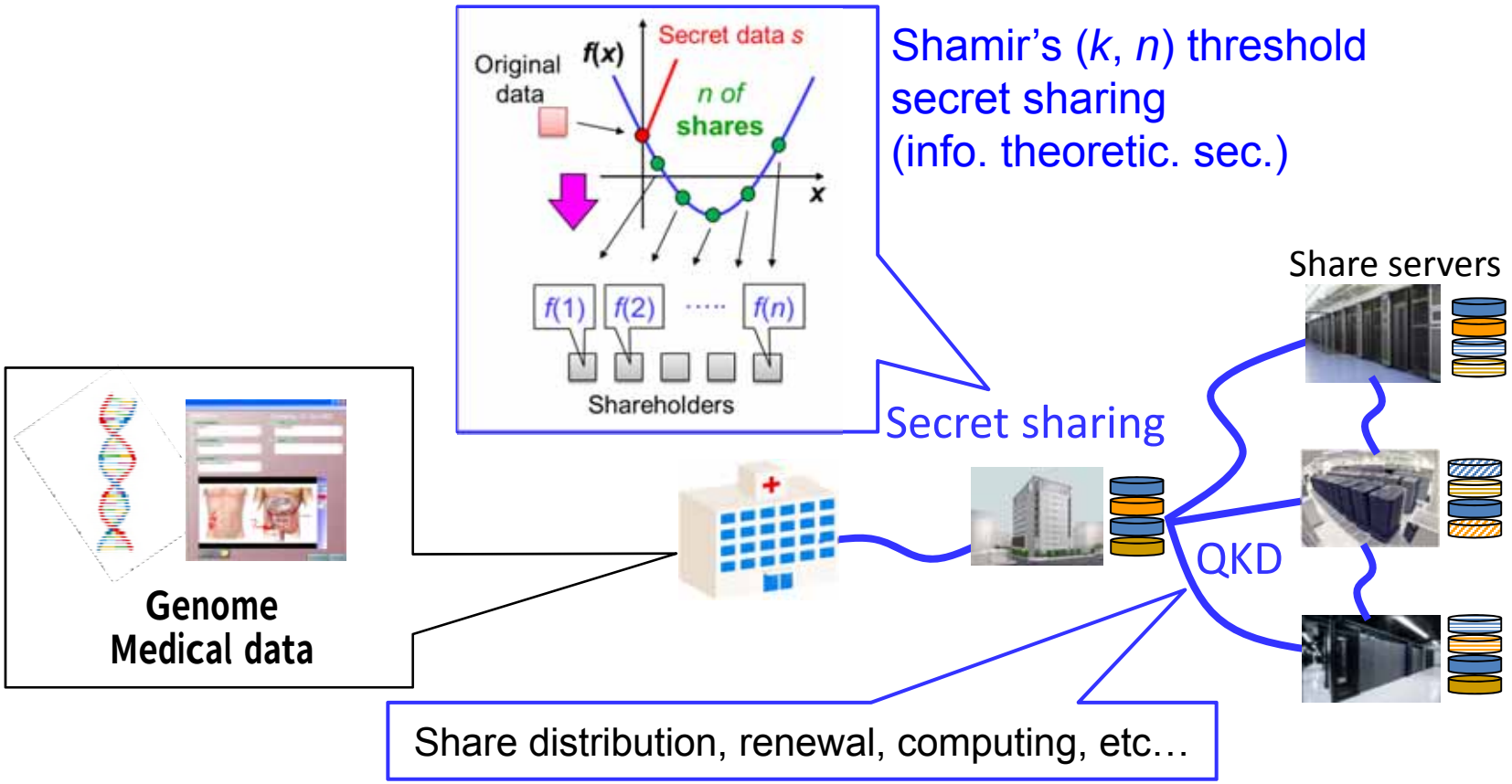
(3) Time-stamp chains of signature

(2) QKD + OTP

2. Computational but prolongable integrity

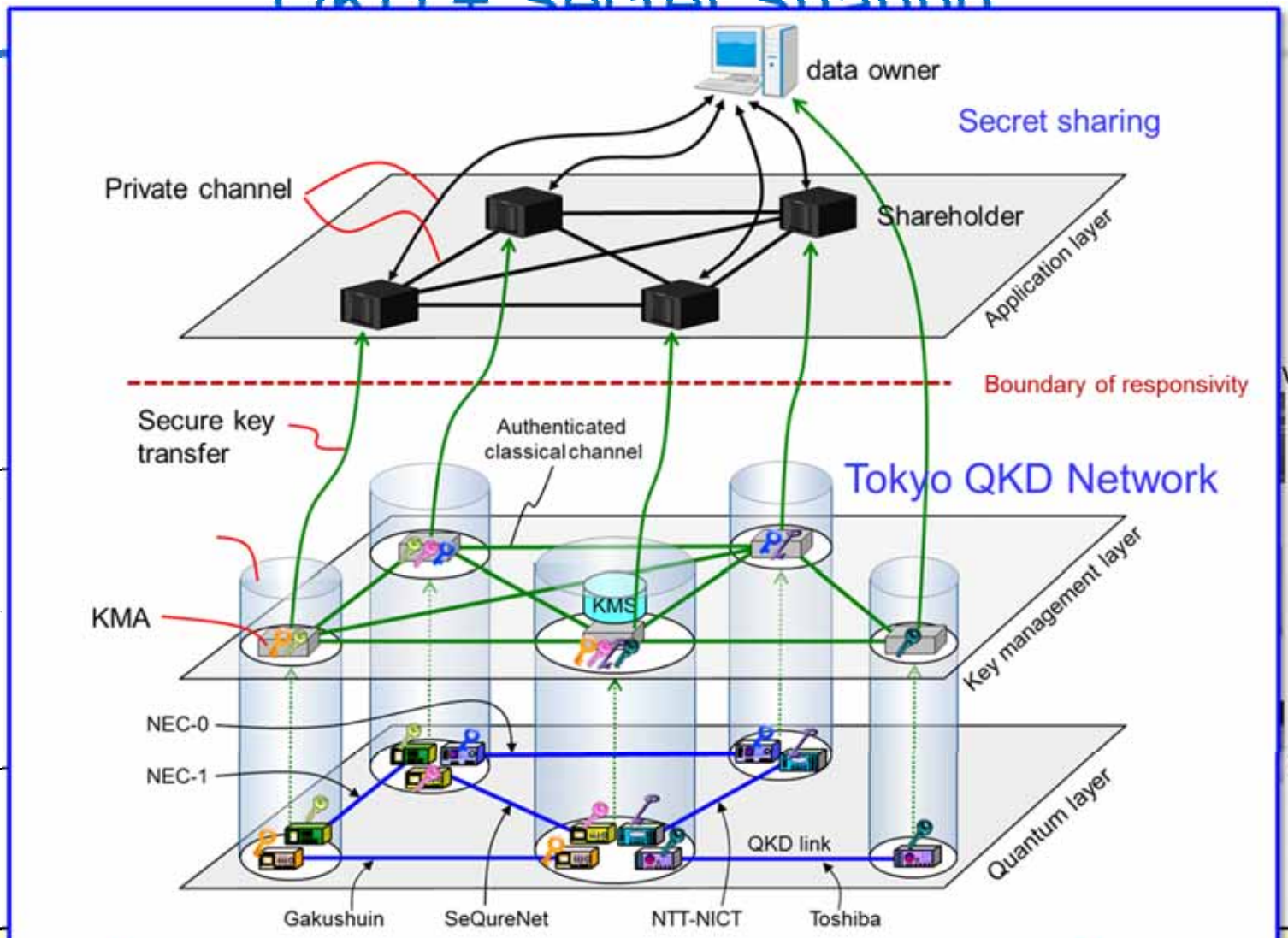
1. Information theoretic confidentiality of data link

QKD + Secret Sharing



- ✓ Confidentiality, integrity (total information theoretic security)
- ✓ Availability, redundancy (data backup)
- ✓ Functionality (data processing without decryption)

QKD + Secret Sharing

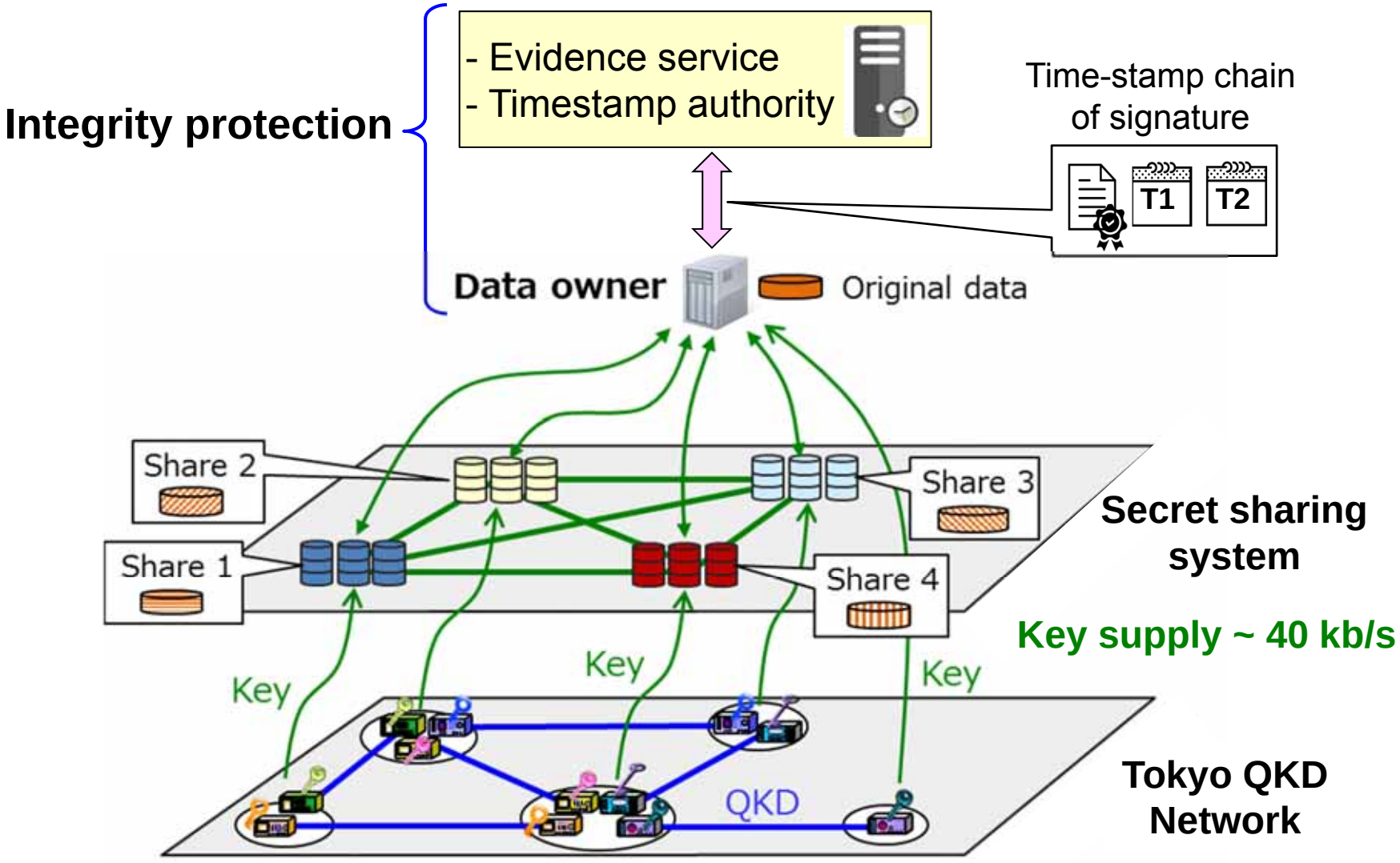


First field demonstration

Fujiwara, et al., Scientific Reports, 6:28988 (2016).

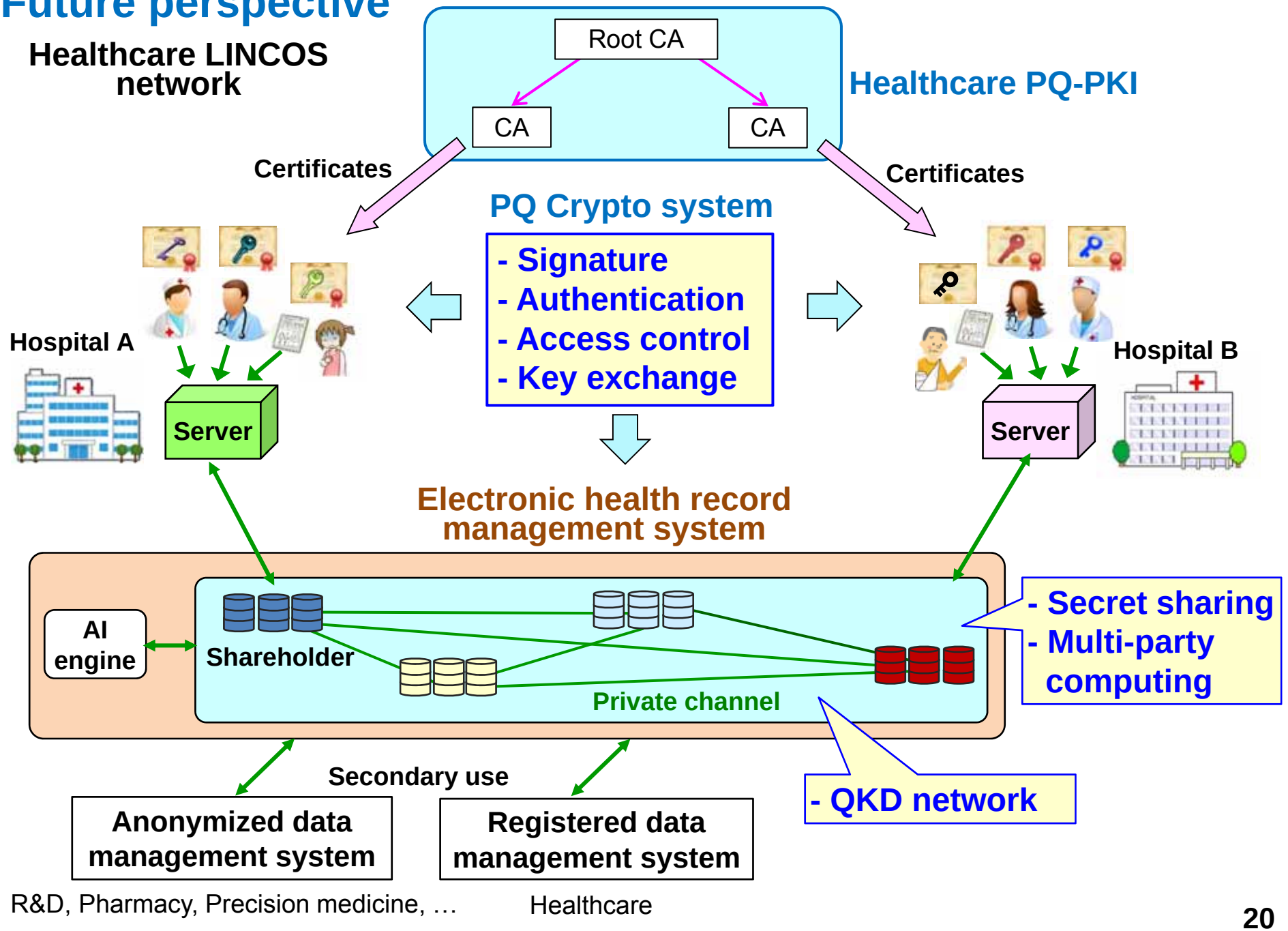
Proof of concept demonstration of LINCOS

J. Braun et al., Proc. ACM Asia CCS2017, pp. 461-468.; ePrint 2016/742



Max link distance ~ 90km

Future perspective



Summary

- Tokyo QKD Network:

  actively working QKD network testbed since 2010
- LINCOS: long-term integrity, authenticity, and confidentiality protection system
  - Confidentiality protection: secret sharing & QKDN

    ⇨ Information theoretic security
  - Integrity protection: timestamp chains of signature
  - Authentication and access control

    ⇨ Prolongable security (not necessarily IT-sec)

Collaborators