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A Study on Zero-touch-design Information-centric Wireless Sensor Networks

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Biography

Shintaro Mori received his B.S., M.S., and Ph.D. degrees from Kagawa University in 2007, 2009, and 2014, respectively. Since April 2014, he has been with the Department of Electronics Engineering and Computer Science, Faculty of Engineering, Fukuoka University, Japan, where he is currently an assistant professor. His research interests include cross-layer design and wireless sensor networks. He is a member of IEEE, IEICE, ISSJ, and RISP.

For more information, please see my website:

https://www.cross-layer.com/

Topics of Research Interest

- Green information-centric wireless sensor networks
- Smart city application for ICWSNs
- Blockchain technologies for ICWSNs
- Information-centric wireless sensor networks (ICWSNs)
- Unmanned aerial vehicle-assisted WSNs
- Wireless sensor networks (WSNs)
- Low-power wide area networks
- Wireless communications and cross-layer design

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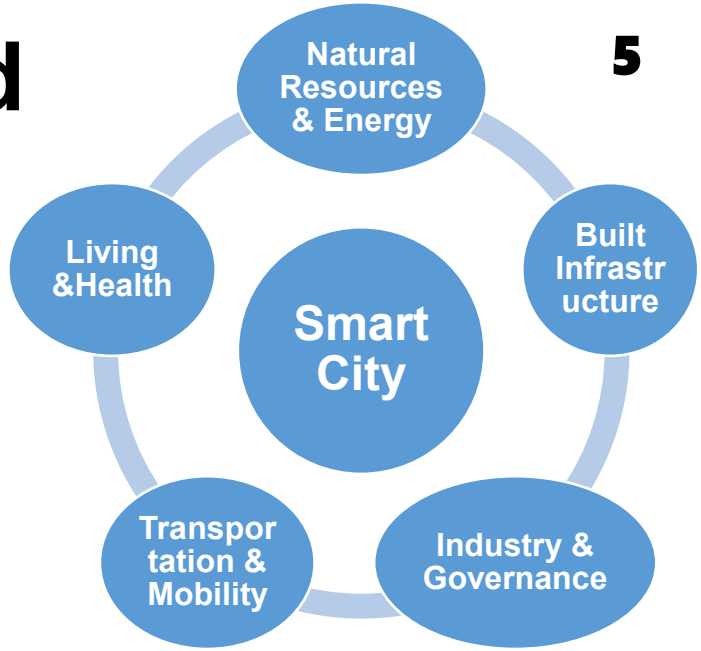
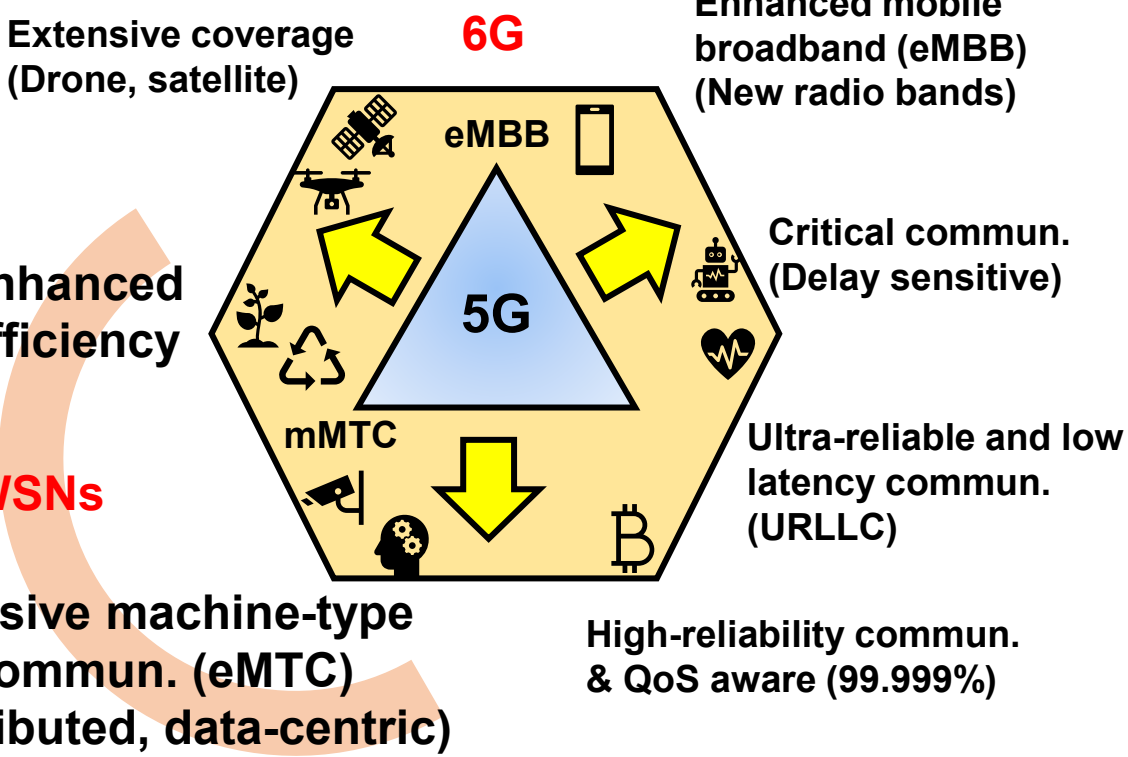
Agenda

- Background
- Ongoing research project
- Objective and contribution
- Information-centric wireless sensor networks
- Zero-touch technologies
- Proposed Scheme
- Computer simulations
- Conclusions

Background

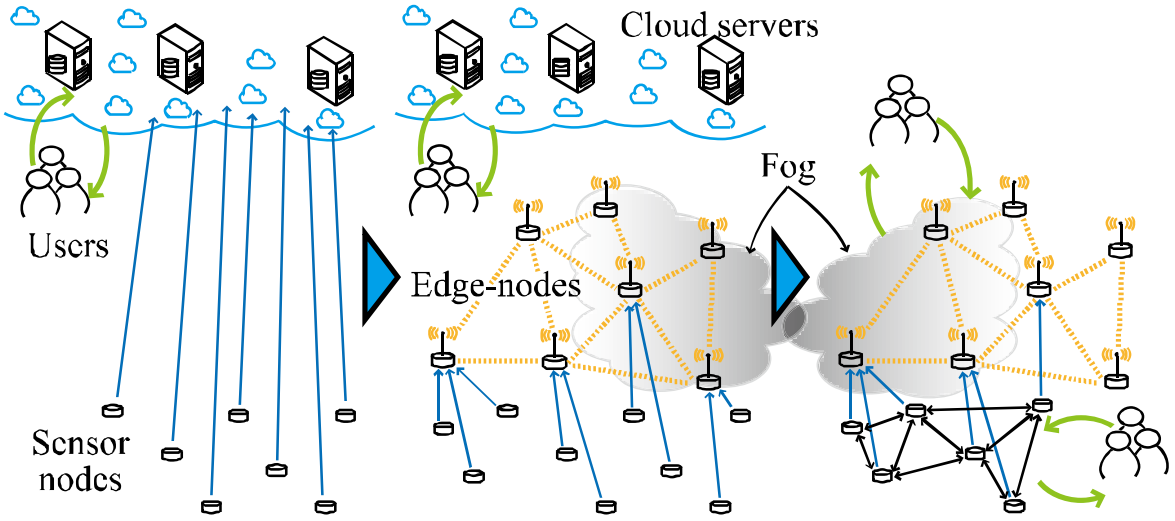
- The Internet of Things (IoT) has stimulated new trends and empowered innovative new developments in smart devices.
- The deployment of such devices at distributed locations is a typical scenario in smart-city applications.
- Further, in next-generation wireless networks, such as beyond Fifth-Generation (5G), massive Sensor Nodes (SNs) might be deployed in a heterogeneous environment across multiple network domains and versatile service slices.





Background

- Wireless Sensor Networks (WSNs) are an elemental technology in this regard, and they require rapid deployment, initial configuration, and sensing-data provisioning, which remain major challenges.
- For scalability and sustainability, the IoT platform must be shifted from a centralized cloud-based framework to an autonomous-decentralized-based one that provides access to various end-users and applications ranging from individuals to enterprises or governments [1].



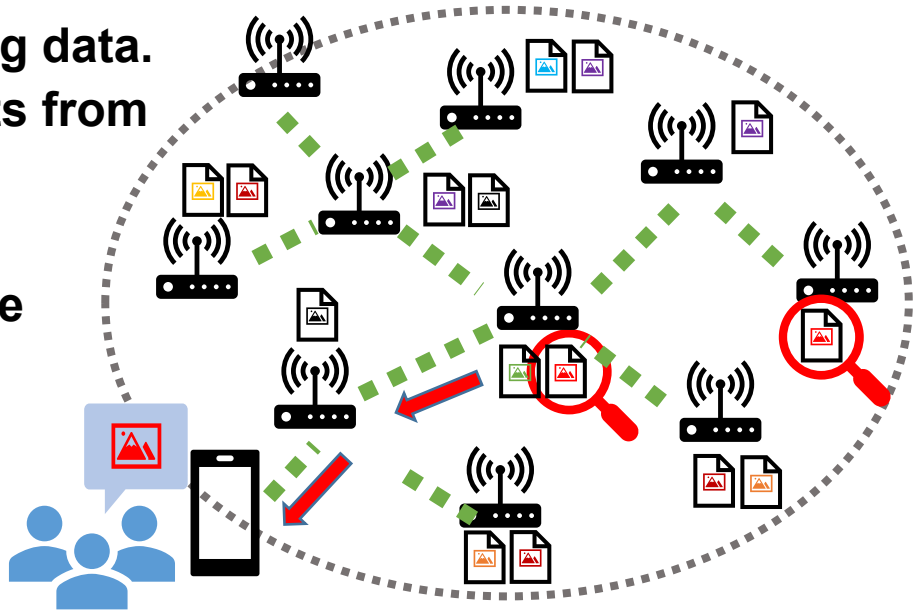
(a) legacy cloud-based IoT framework (b) Current edge-based (fog-based) IoT framework (c) Future information-centric distributed IoT framework

[1] H. Chergui et al., "Toward zero-touch management and orchestration of massive deployment of network slices in 6G," *IEEE Wireless Commun.*, vol. 29, no. 1, pp. 86–93, Feb. 2022.

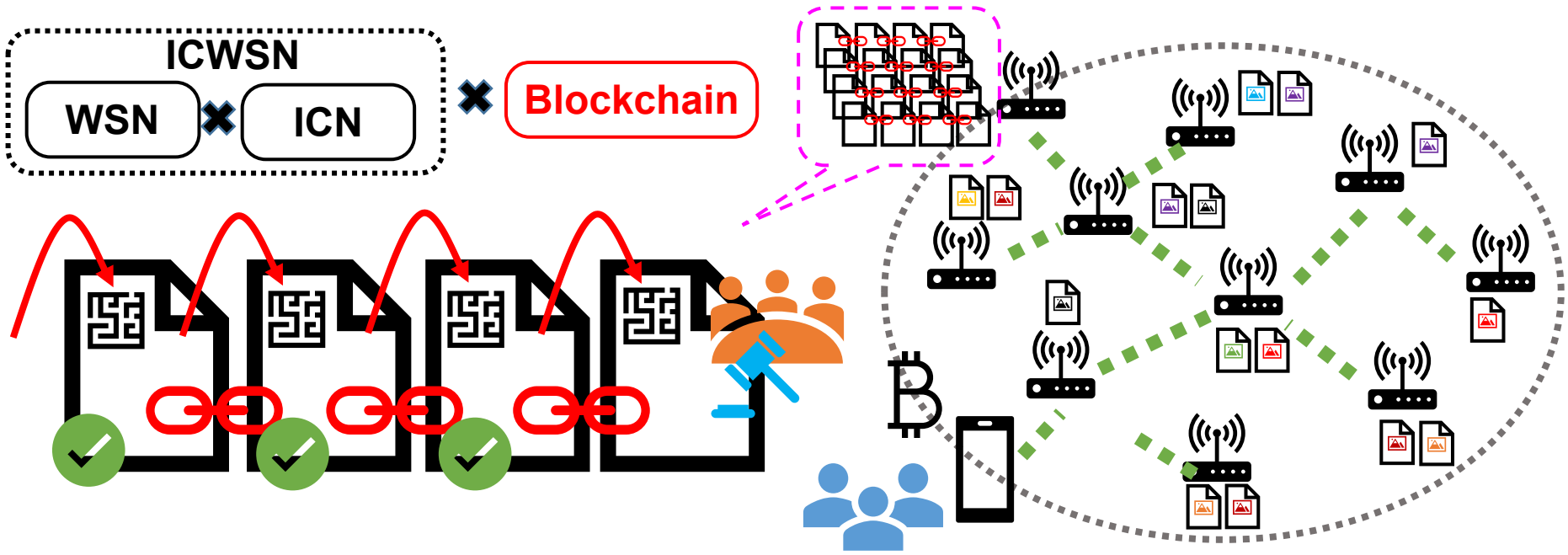
Information-centric wireless sensor networks (ICWSNs)

- As for the data-centric techniques, an Information-Centric Network (ICN) (e.g., a content-centric network or named-data network) can renovate current network protocols, such as the Internet.

- ICN natively supports functionalities, such as abstraction, naming, and in-network caching, which enables the data to be decoupled from its original location and the security of every data to be adopted in the network layer.
  - Any node can copy/store the caching data.
  - ICWSNs can reply to further requests from the cache memories.
- Combining ICN with WSNs is suitable for an autonomous-decentralized environment, which yields Information-Centric Wireless Sensor Networks (ICWSNs).



Ongoing research project

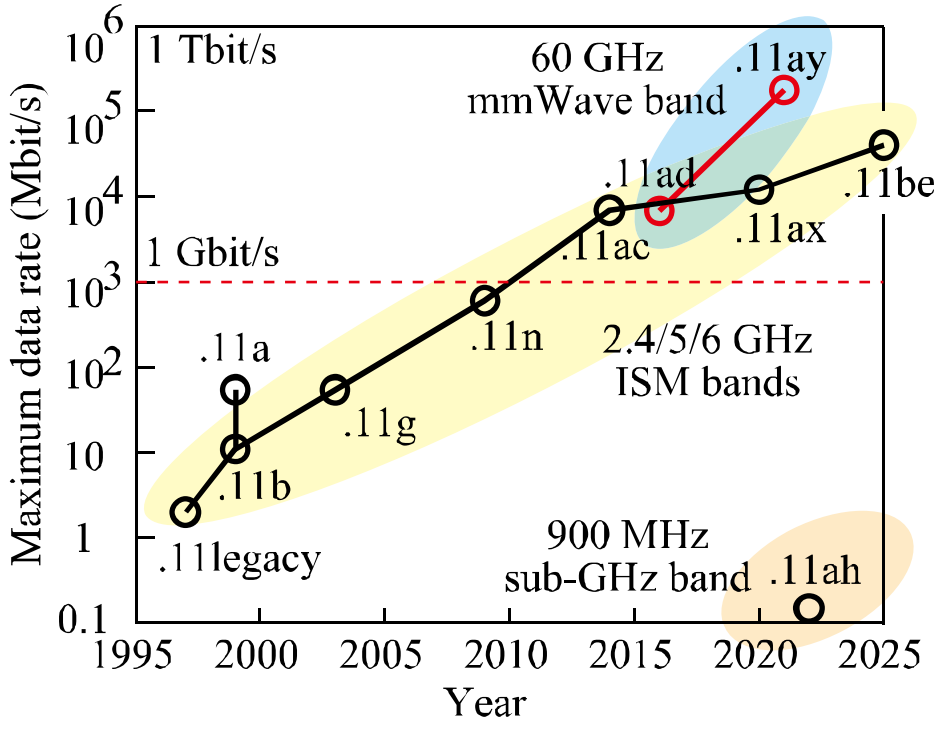


- In our previous study [2], an ICWSN-based ecosystem with a blockchain for smart-city applications was investigated on the basis of a scheme that achieves efficient and reliable caching.
  - Blockchain is suitable for ICWSNs with improved integrity, traceability, interoperability, and scalability.
  - Once data have been registered with a common consensus protocol, it can be prevented from rewriting.

[2] S. Mori, "Information-centric wireless sensor networks for smart-city-as-a service: Concept proposal, testbed development, and fundamental evaluation," *Proc. IEEE CCNC*, Jan. 2023, pp. 945–946.

Ongoing research project

- In our ongoing research project, which we call the Decentralized Digital twins' Ecosystem (D2EcoSys), we have developed a portable testbed device, and evaluated its applicability to mmWave-band Wireless Fidelity (Wi-Fi), e.g., IEEE 8012.11 ad/ay, towards deployment for on-site testing.



[2] S. Mori, "Information-centric wireless sensor networks for smart-city-as-a service: Concept proposal, testbed development, and fundamental evaluation," *Proc. IEEE CCNC*, Jan. 2023, pp. 945–946.

Objective and contribution

- In light of this background, we focus on two key techniques:
  - Zero-touch
  - Data-centric

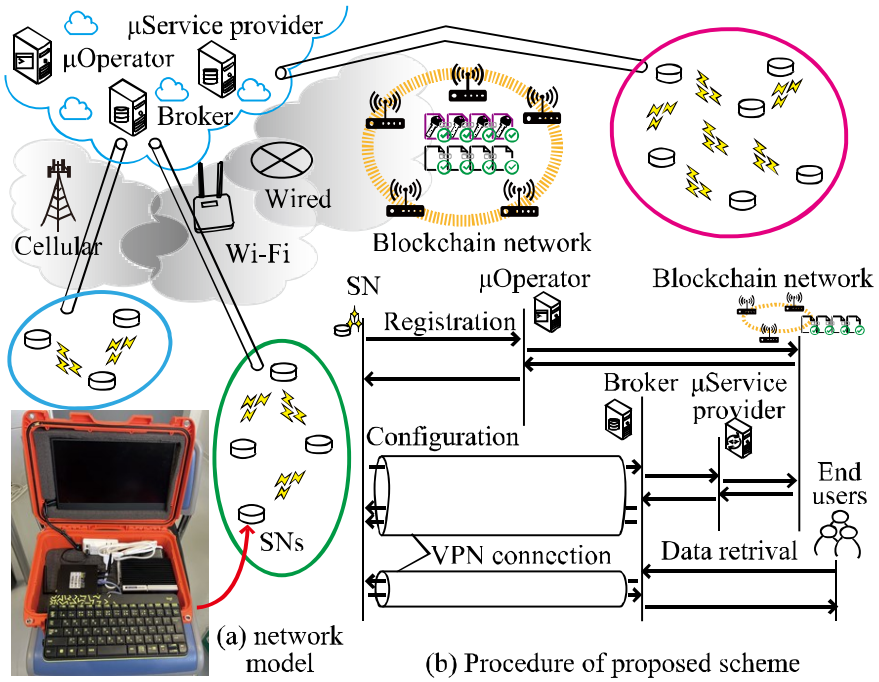
- The current paper provides a blueprint of zero-touch-design ICWSNs to promote self-growing and ensure a reliable sensing-data distribution in which multiple players actively participate and exchange data.
- The computer simulation was conducted to investigate energy consumption, as the potential waste involved in the use of ICN and blockchain is significant.

[1] H. Chergui et al., "Toward zero-touch management and orchestration of massive deployment of network slices in 6G," *IEEE Wireless Commun.*, vol. 29, no. 1, pp. 86–93, Feb. 2022.

Zero-touch technology

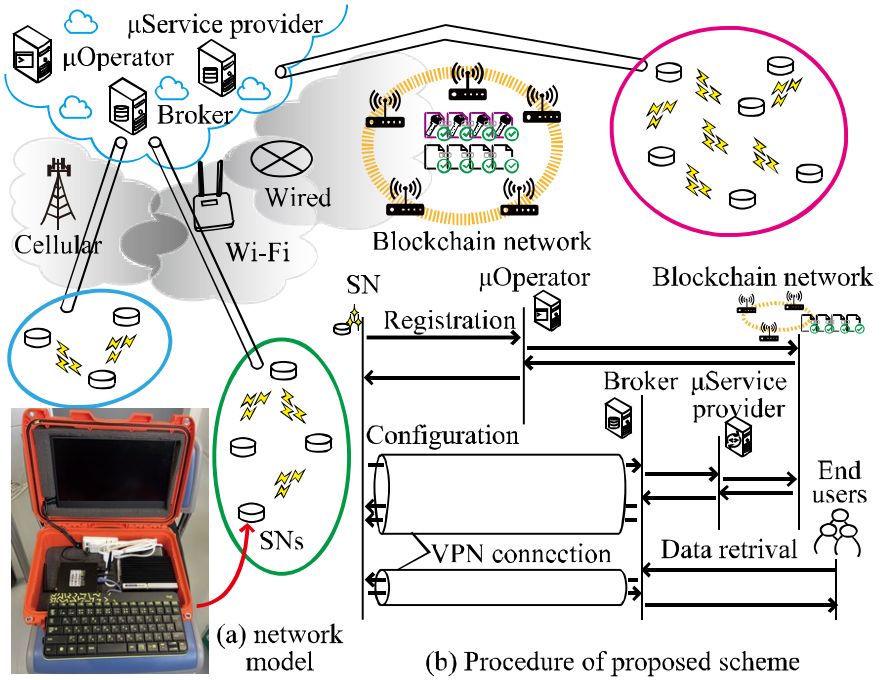
- Zero-touch technology aims at completely automating the network-management process to minimize operating costs and set up individual execution environments.
- A zero-touch-design system was utilized in the first Linux operating system and has since led to the demand for service deployments that are versatile and flexible in cloud-native micro-services.

- In zero-touch-design ICWSNs, the first step is to enable automatic participation in the network, i.e., the network trusts an individual SN through the device owner when the SN joins a member of ICWSNs.
- This procedure requires comprehensive involvement from device owners, micro-(network) operators, and micro-service (roaming) providers



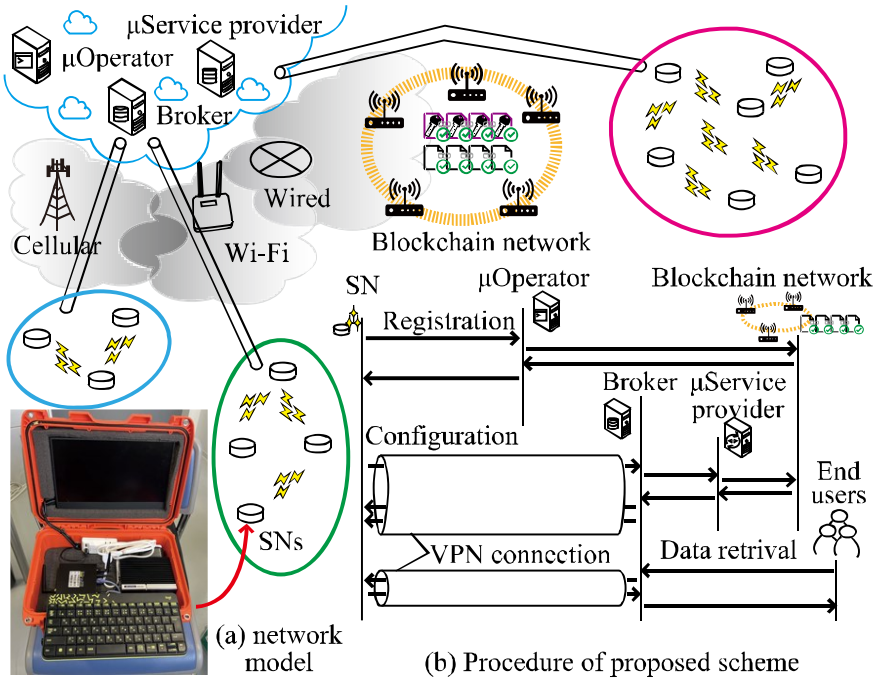
Proposed scheme

- For the management of terminal information, the proposed scheme utilizes blockchain-based ledgers.
  - It obtains the SN identification information from the blockchain network, which plays an instrumental role in the execution of smart contracts.



- The scheme guarantees the trustworthiness of the SN during an initial process, i.e., it considers that the data generated by a reliable SN can be trusted without receiving any verification from the blockchain network.
- For this reason, the blockchain-based storage for the data no longer requires traditional computation-intensive mining, and the blockchain can simply select alternative consensus schemes, such as proof-of-authority or proof-of-elapsed-time algorithms.

Proposed scheme



- When an SN device is turned on, it sends a registration request to the uOperator and establishes a secure Virtual Private Network (VPN) link.
- An ICWSN with a VPN implements the orchestration of distant ICWSNs, terminal fixation at the datalink (L2) layer, and secure data exchanges.
- After joining the network, the SN downloads and installs a configuration setting and application software from the uService provider.

Computer simulations

- The difficulty in deploying the proposed scheme is how to ensure any benefit in terms of energy consumption among the SN devices.
- This is because ICN has a pull-type network design and must always be on standby, and the blockchain also causes energy wastage.
- The simulation condition:
  - The computer simulator was implemented using the C++ language.
  - The generation and transmission of sensing data respectively correspond to the status of calculation and wireless communication
  - When the SN does not execute any process, we assume the conventional scheme supports a sleep state with deep sleep and wake-up functionalities, whereas the proposed scheme waits in the idle state to be ready for data retrieval from any other node (because of the pull-type data acquisition).
  - The energy consumption for each status is based on the actual measured values from our previous study [3].

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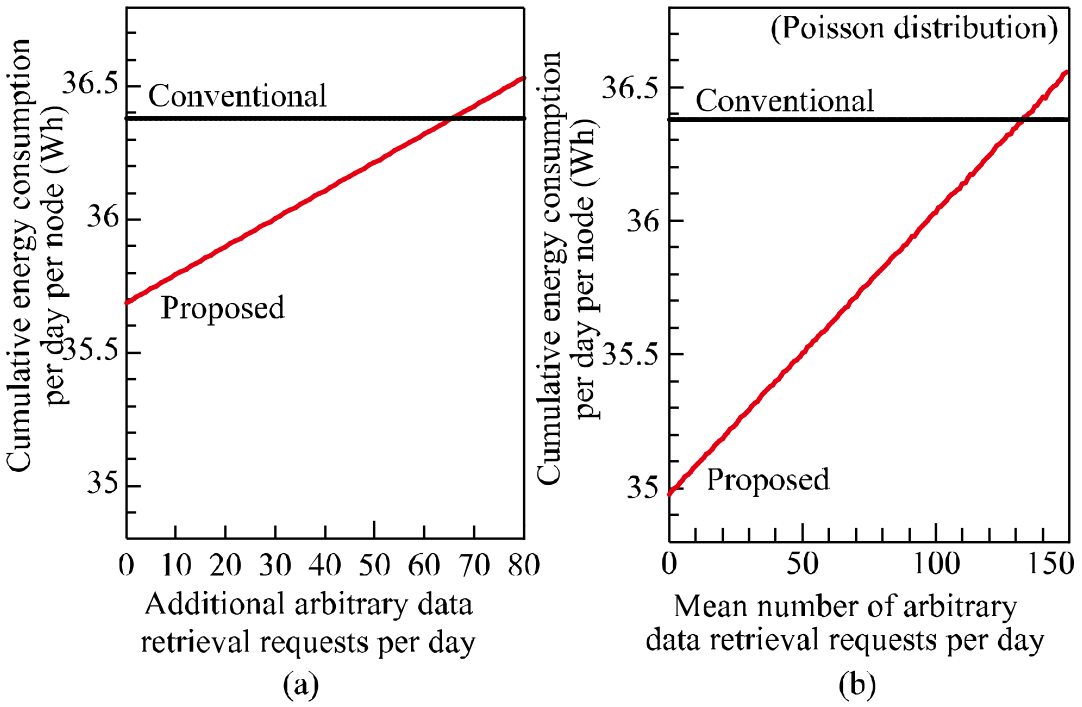
[3] S. Mori, "A preliminary analysis of data collection and retrieval scheme for green information-centric wireless sensor networks," *Proc. ACM SigComm WS Net4us*, Aug. 2022, pp. 1–6, doi: https://dl.acm.org/doi/10.1145/3538393.3544932.

Computer simulations

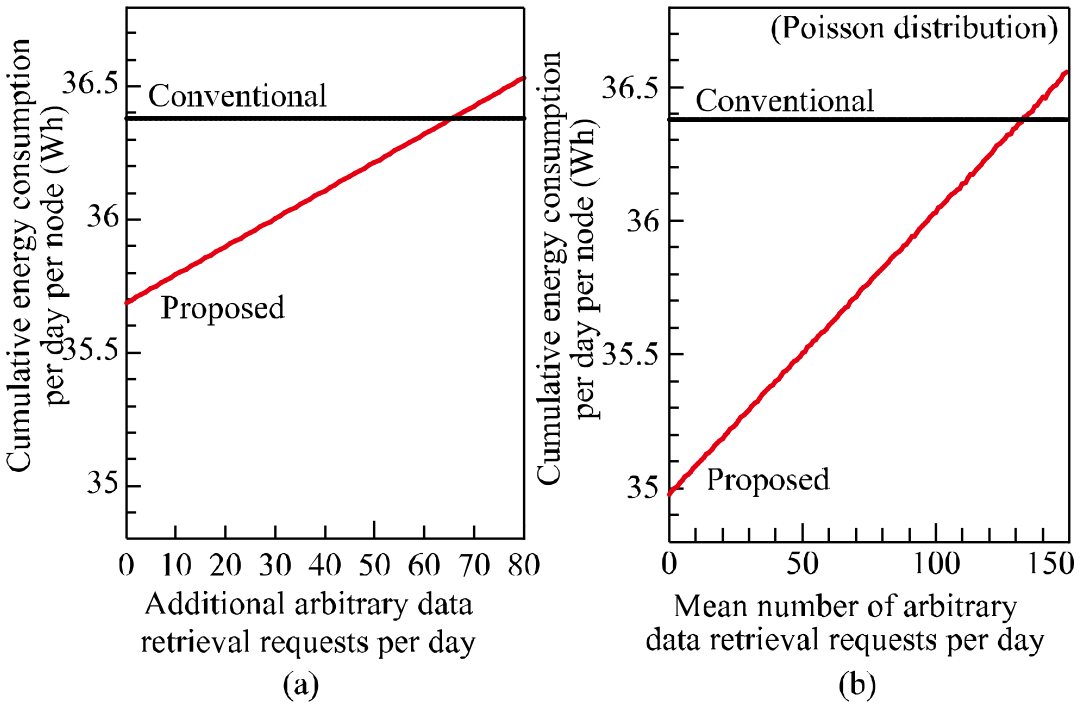


- We evaluate the cumulative energy consumption with the conventional scheme (current application-programming-interface-based IoT platform).
- Simulation results:

  (a) additional data retrieval requests per day vs. cumulative energy consumption.

  (b) mean number of additional requests according to a Poisson distribution vs. cumulative energy consumption per unit for 1,000 SNs.

Computer simulations



- **Discussions:**
  - **The proposed scheme can reduce energy consumption by 1.91% if there are no additional requests for data retrieval in most cases of periodic data collection in ordinary situations.**
  - **Even if 66 additional data retrievals per day are requested, the proposed scheme can outperform.**
  - **The proposed scheme can reduce energy consumption by 3.85% and be advantageous until 138 retrieval attempts.**

Conclusions

- **Contribution:**
  - A zero-touch-design ICWSN for a smart-city-as-a-service that promotes self-growing in autonomous-distributed conditions.
- **Future work:**
  - Testbed development, deployment, and on-site demonstration of the scheme in realistic smart cities are currently working in progress.
- **Related work:**
  - Togou et al. [4] developed a distributed blockchain-enabled network slicing framework.
  - Nour et al. [5] introduced a network slice and resource provider utilizing a blockchain in which the scheme could shift from a network-operator-oriented architecture to a more open system with multiple actors.
  - Rathi et al. [6] provided a blockchain-based management and orchestration technique for multi-domain networks.

[4] M. A. Togou et al., "DBNS: A distributed blockchain-enabled network slicing framework for 5G networks," IEEE Commun. Mag., vol. 58, no. 11, pp. 90–96, Nov. 2020.
[5] B. Nour et al., "A blockchain-based network slice broker for 5G services," *IEEE Networking Lett.*, vol. 1, no. 3, pp. 99–102, Sept. 2019.
[6] V. K. Rathi et al., "A blockchain-enabled multi domain edge computing orchestrator," IEEE Internet of Things Mag., vol. 3, no. 2, pp. 30–36, June 2020.

Thank you for your kind attention

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