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

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***Abstract*—This paper describes a novel zero-touch-design information-centric wireless sensor network for smart-city applications. To promote self-growing in the autonomous-distributed environment, the proposed scheme adopts a mechanism of zero-touch technology focusing on the lower layers in which sensor nodes join the network. The results of preliminary computer simulations demonstrate the effectiveness of the proposed scheme in terms of energy consumption. This study is a part of our ongoing research project to develop an ecosystem that enables a smart-city-as-a-service platform, where we are currently focused on the development and experimental trials in on-site testing.**

Keywords-Information-centric wireless sensor networks; Zero-touch-design; Smart-city-as-a-service platform

I. Introduction

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. 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. 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. Therefore, 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].

In light of this background, we focus on two key techniques: zero-touch and data-centric. 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. 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

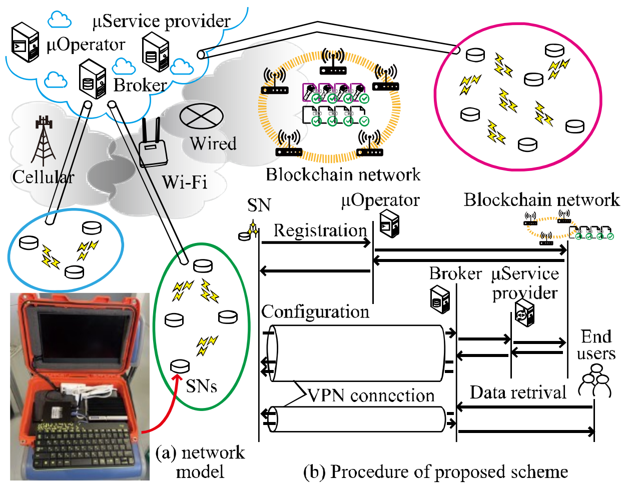

Figure 1. Overview of proposed scheme

data to be adopted in the network layer. Combining ICN with WSNs is suitable for an autonomous-decentralized environment, which yields Information-Centric Wireless Sensor Networks (ICWSNs).

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. In our ongoing research project, which we call the Decentralized Digital twins' Ecosystem (D^2EcoSys), 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. 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.

The remainder of this paper is organized as follows. Section II describes the proposed scheme and Section III presents the numerical results. In Section IV, we provide related works and. We conclude in Section V with a brief summary and findings.

II. Proposed Scheme

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

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a member of ICWSNs. This procedure requires comprehensive involvement from device owners, micro-(network) operators, and micro-service (roaming) providers, as shown in Figure 1. For the management of terminal information, the proposed scheme utilizes blockchain-based ledgers. Specifically, 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 [2]. 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.

When an SN device is turned on, it sends a registration request to the uOperator and establishes a secure Virtual Private Network (VPN) link if approved. 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.

III. Numerical Results

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. Figure 2 shows the computer simulation we ran to compare the cumulative energy consumption with the conventional scheme (current application-programming-interface-based IoT platform). The computer simulator was implemented using the C++ language. The simulation condition is that the generation and transmission of sensing data respectively correspond to the status of calculation and wireless communication. In addition, 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].

As shown in Figure 2(a), 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. Moreover, even if 66 additional data retrievals per day are requested, the proposed scheme can outperform. Next, Figure 2(b) shows the total energy consumption in the ICWSN for 1,000 SNs, with the results converted into the power consumption per node. For these results, the number of data retrieval attempts for each node was determined by a Poisson distribution, which is a more realistic calculation than the one in Figure 2(a). As we can see from the figures, the proposed scheme can reduce energy consumption by 3.85% and be advantageous until 138 retrieval attempts.

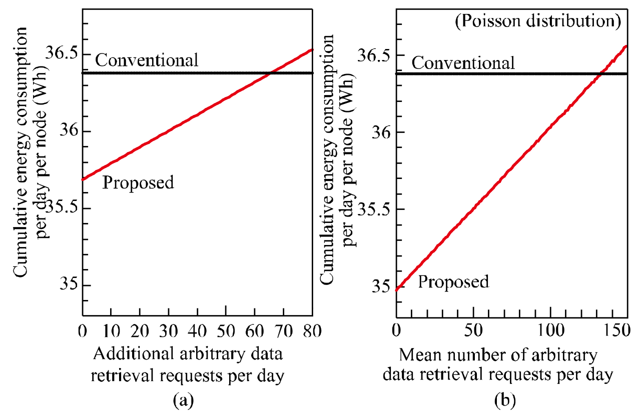

Figure 2. Simulation results: (a) additional data retrieval requests per day vs. cumulative energy consumption, and (b) mean number of additional requests according to a Poisson distribution vs. cumulative energy consumption per unit for 1,000 SNs.

IV. 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.

V. Conclusion

This paper described a zero-touch-design ICWSN for a smart-city-as-a-service platform along with a scheme that promotes self-growing in autonomous-distributed conditions. The results of a preliminary numerical investigation indicated that the proposed scheme could effectively reduce energy consumption. Testbed development, deployment, and on-site demonstration of the scheme in realistic smart cities are currently working in progress.

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