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Hong, Choong Seon
Kyung Hee University
Munir, Md. Shirajum
Kyung Hee University
Kitae Kim
Kyung Hee University
Seok Won Kang
Kyung Hee University

Proactive energy management for smart city with edge computing using meta-reinforcement learning scheme

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Abstract

Renewable energy enabled sustainable energy management ensures a high degree of reliability in order to fulfill the energy demand of a smart city. In such case, renewable energy generation is random over time and also energy consumption of smart city users' is nondeterministic in nature. Therefore, to ensure sustainable energy management for smart city, a proactive energy management scheme should be integrated into smart city network. In which, edge node should be considered as local computational unit for each energy user and microgrid controller should be played the role of energy management decision aggregator. As a result, proactive energy management scheme not only overcomes the challenges of renewable energy-aware demand scheduling but also establishes a strong relationship for both energy generation and consumption over time. Therefore, a distributed mechanism is considered, where the edge node for executing local agent to determine an individual users' policy with respect to energy consumption and renewable energy generation (users' own sources). On the other hand, microgrid controller determines meta-policy through a meta-agent with Recurrent Neural Network (RNN). Since a meta-agent accepts local policy as an input with historical observations, which ensures fast and efficient execution of proactive energy management for the smart city.

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1. Introduction

In the modern development arena, smart city, and renewable energy are indispensable toward the ecological growth of urban technology to enable sustainable smart services [a,b]. A microgrid is capable to fulfill that huge amount of energy demand by enabling the efficient demand scheduling of smart city energy consumptions. However, the challenges come with the unpredictable nature of both energy consumption and renewable generation, which also have a strong relationship over the history of energy consumption and generation [c,d].

Therefore, to overcome those challenges, a proactive energy management is essential such that both energy consumption and renewable energy generation can be considered. In order to do that, meta-reinforcement learning (Meta-RL)-based [e] energy scheduling model, in which this method is capable of handling both energy consumption and generation with the historical and current observations using Recurrent Neural Network (RNN).

Proactive energy management for the smart city should be solved by distributed manner.

- First, a local agent with an edge computing facility determines a local policy with respect to energy consumption and generation (user’s own renewable sources) for its nearby energy users’.

- Second, by reusing the historical observations and local policy, the microgrid controller estimates the meta-policy for energy scheduling. Further, it takes necessary action based on meta-policy to enable sustainable energy management for the smart city.

1.1. Terminology and Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2.   Energy Data Flow Management

The Microgrid-powered smart city includes both renewable and non-renewable energy sources, where each individual building has its own renewable (solar) energy sources. The city connected with edge computing enabled wireless networks to fulfill smart city services. Each energy user (i.e., home, building, school, commercial building, and so on) is associated with its nearby edge computing server. Energy demand, renewable generation, and required amount should send to its associated edge server. Based on each user data, edge server determine its own local energy management policy by applying Deep Q-learning. The output (reward(t), action(t) reward(t-1), action(t-1)) should send to microgrid controller. Microgrid controller decides the overall energy management policy for the smart city and send feed back to each user via edge server. The communication should be through the wireless communications protocol (LTE, 5G, LTU, Wifi, etc.) for exchanging the energy management data.

2.1. Energy Data Flow

Energy data flow of proactive energy management for smart city as shown in Figure 1.

. Energy user with renewable energy sources can send energy demand and generation raw data to MEC Server # in smart city network

. Each energy user's observational data (reward and action) by executing reinforcement learning (Deep Q-learning) from MEC should send to microgrid controller

. Other energy sources (except the energy sources that are associated with smart city user) should send to microgrid controller

. Microgrid controller send the energy management executing command to each users’

Figure 1: Energy data flow of proactive energy management for smart city

2.2 Energy Data Format

The data format complies with tuple.
Figure 2 represent the data format of proactive energy management scheme.

Figure 2: Energy data format of proactive energy management for smart city

3. Proactive Energy Management for Smart City

Each edge server estimates the local policy for the associated energy users while Microgrid controller determines the meta policy using a little amount of information from local policy. Establishing a strong correlation between energy generation and consumption using Markovian properties for each energy user.

3.1 Meta-Reinforcement Learning with Edge Computing

The proactive energy demand scheduling for smart city problem is solved distributively, where first, obtain the local policy by learning the local agent with respect to energy consumption and renewable energy generation through the nearby edge server. Second, in order to generate meta-policy, we send local policy information to the microgrid controller alone with previous policy observation, so that meta-agent can learn very fast with the optimal decision. This procedure is the same for every energy user and meta-RL model procedure is shown in Figure 3.

Figure 3: Proactive energy management for smart city using Meta-RL

3.2. Process flow of proactive energy management

Process flow of proactive energy management is illustrated in Figure 4.

. Energy generation and demand data from all users at associated edge server

. Local policy estimation process for each user’s at the edge server using DQN and observation data by local agent send to microgrid controller

. Meta energy management policy estimation using local policy at microgrid controller and action command send to user through edge server

. Apply energy management policy to smart city users by the edge server service

Figure 4: Process flow of proactive energy management for smart city

4. IANA Considerations

There are no IANA considerations related to this document.

5. Security Considerations

This note touches communication security as in wireless communications protocol (LTE, 5G, LTU, Wifi, etc.).

6. References

6.1. Normative References

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6.2. Informative References

Authors' Addresses

Choong Seon Hong
Computer Science and Engineering Department, Kyung Hee University
Yongin, South Korea
Phone: +82 (0)31 201 2532
Email: cshong@khu.ac.kr
Md. Shirajum Munir
Computer Science and Engineering Department, Kyung Hee University
Yongin, South Korea
Phone: +82 (0)31 201 2987
Email: munir@khu.ac.kr
Ki Tae Kim
Computer Science and Engineering Department, Kyung Hee University
Yongin, South Korea
Phone: +82 (0)31 201 2532
Email: glideslope@khu.ac.kr
Seok Won Kang
Computer Science and Engineering Department, Kyung Hee University
Yongin, South Korea
Phone: +82 (0)31 201 2532
Email: dudtntdud@khu.ac.kr