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Epsilon-Greedy-Based MQTT QoS Mode Selection and Power Control Algorithm for Power Distribution IoT

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ABSTRACT

Employing message queuing telemetry transport (MQTT) in the power distribution internet of things (PD-IoT) can meet the demands of reliable data transmission while significantly reducing energy consumption through the dynamic and flexible selection of three different quality of service (QoS) modes and power control. However, there are still some challenges, including incomplete information, coupling of optimization variables, and dynamic tradeoff between packet-loss ratio and energy consumption. In this paper, the authors propose a joint optimization algorithm named EMMA for MQTT QoS mode selection and power control based on the epsilon-greedy algorithm. Firstly, the joint optimization problem of MQTT QoS mode selection and power control is modeled as a multi-armed bandit (MAB) problem. Secondly, the authors leverage the online learning capability of the epsilon-greedy algorithm to achieve joint optimization of MQTT QoS mode selection and power control. Finally, they verify the superior performance of the proposed algorithm through simulations.

KEYWORDS

Energy Consumption, Epsilon-Greedy Algorithm, Message Queuing Telemetry Transport, Multi-Armed Bandit, Packet-Loss Ratio, Power Control, Power Distribution Internet of Things, QoS Mode Selection

1. INTRODUCTION

1.1 Background

Power distribution internet of things (PD-IoT) realizes comprehensive perception, data fusion, and intelligent applications of the distribution network through the interconnection and intercommunication between power distribution network devices (Lv J. *et al.*, 2018; Liu J. *et al.*, 2018; Liu Z., 2016). With the rapid development of IoT technology in the distribution network and the significantly increasing number of PD-IoT devices, the traditional request/response mechanism is no longer suitable (Kim G. *et al.*, 2019; Stankovic J. A., 2020). Moreover, due to the limited battery capacity and computation

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resources of PD-IoT devices, it is difficult to meet the quality of service (QoS) requirements of the low packet-loss ratio and low energy consumption in PD-IoT (Zhou Z. *et al.*, 2020; Mumtaz S. *et al.*, 2017; Ding Z. *et al.*, 2019; Liao H. *et al.*, 2020; Sadio O. *et al.*, 2019). Therefore, how to ensure the QoS requirements of PD-IoT devices with limited resources is a difficult problem.

Message queue telemetry transmission (MQTT) provides an effective solution as an IoT transmission protocol based on publish/subscribe mechanism, which has the characteristics of simple implementation, lightweight, and high bandwidth utilization (Sadio O. *et al.*, 2019; Herrero, R. *et al.*, 2019). Specifically, it provides three flexible QoS modes to achieve the reliable transmission of different task data, i.e., "at most once QoS0", "at least once QoS1", and "exactly once QoS2", which are introduced as follows:

At most once QoS0: Named as "QoS0 mode", sender sends a PUBLISH data packet containing the message to the receiver, and each PUBLISH data packet is sent only once, regardless of whether the receiver successfully receives the PUBLISH data packet. Therefore, although the energy consumption of QoS0 mode is low, the high packet-loss ratio is caused when the channel state is poor or the power control is lacking.

At least once QoS1: Named as "QoS1 mode". Each PUBLISH data packet is guaranteed to be received successfully at least once. If the feedback confirmation data packet, i.e., the PUBACK data packet is not received by the sender within a period of time, the PUBLISH data packet will be retransmitted. The data deduplication energy consumption is introduced while the packet-loss ratio is zero.

Exactly once QoS2: Named as "QoS2 mode". The QoS2 mode ensures that each PUBLISH data packet is only successfully received by the receiver once through two interaction processes. If a data packet with the same information header as the previously stored information header is received, the receiver will treat it as a duplicate message and discard it. Therefore, the energy consumption of deduplication is avoided at the cost of increasing the energy consumption of transmission considering the two interaction processes in the QoS2 mode.

In summary, different QoS modes have different performance in terms of packet-loss ratio and energy consumption. In addition, power control also affects the packet-loss ratio and energy consumption simultaneously by adjusting the allocated transmission power. Therefore, in order to achieve a dynamic tradeoff between packet-loss ratio and energy consumption, it is intuitive to jointly optimize the MQTT QoS mode selection and power control.

1.2 Challenge

However, there are still some key technical challenges in the joint optimization of MQTT QoS mode selection and power control. Firstly, the global state information, e.g., channel state information and bandwidth information, is required for the joint optimization problem, which is unavailable for PD-IoT devices in the actual implementation environment considering the prohibitive signaling overhead. Secondly, the optimization problem is a non-deterministic polynomial (NP)-hard problem due to the coupling between MQTT QoS mode selection and power control. Specifically, a larger transmission power is required to ensure the successive transmission when the QoS0 mode is selected. Moreover, this exacerbates the complexity of the optimization problem. Last but not least, it is unrealistic to achieve the lowest energy consumption and the lowest packet-loss ratio at the same time. For example, when the QoS2 mode is selected, although a low packet-loss ratio is achieved, multiple transmissions of task data packet result in higher energy consumption. If the QoS0 mode is selected, although the energy consumption is lower, the packet-loss ratio increase. Therefore, how to achieve a dynamic tradeoff between packet-loss ratio and energy consumption through the joint optimization of MQTT QoS mode selection and power control under incomplete information to meet the different QoS requirements of PD-IoT services is still an open issue.