

To Reduce Signaling Cost for Smart Grid Alarm System by Using Caching Mechanism

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Abstract— Information and Communication Technologies (ICT) are one of significant elements in the smart grid. Alarm systems are important thing in the ICT of smart grid. A number of sensors are being connected to the Internet. The abundant information technologies and many sensors demand much more data on their systems than before. Also, the alarm systems require a number of signaling. In this paper, we propose hierarchical architecture which reduces the signaling cost by using caching mechanism. Our alarm system operates Message Queue Telemetry Transport (MQTT). We apply caching mechanism in the features of MQTT's functions. The architecture can reduce the signaling cost than non-applying caching mechanism.

Keywords—Smart grid, Alarm, MQTT, Signaling Cost, Hierarchical Architecture, Caching Mechanism

I. INTRODUCTION

Smart Grid is conceptualized as various technologies in power, communication and control. In the bidirectional communication and power flows, a smart grid enables delivering electricity more efficiently and reliably than the traditional power grid. The intelligent entities can communicate and interact autonomously because they efficiently deliver electricity to the customers. Any smart grid infrastructure should support real-time, two-way communication between utilities and consumers, and should allow software systems at both the producer and consumer ends to control and manage the power usage [1].

The energy efficiency and management require the key of the smart grid. Energy management (EM) systems are an important role in monitoring home energy consumption. These systems provide the information about control and optimize energy consumption. For helping consumers, EM systems can avoid power consumption during peak load and provide benefit from notifying information. Many kinds of EM systems will manage more efficient power consumption and will provide benefit [2].

Monitoring and alarming is important functions to detect harmful events early and robustly. In contrast to centralized monitoring systems, distributed solutions do not depend on the presence of (or even the presence of a functioning path to) a global and possibly remote controller. The alarm system brings

more complexities in the system operation since there is larger amount of data and more price signals. It also has placed great importance as to the availability of the grid information and the analysis of grid information. [3]

The number of physical objects has been grown extremely in the smart grid. They are being connected to the Internet at an unprecedented rate realizing the idea of the Internet of Things (IoT). The HVAC (Heating, Ventilation, and Air Conditioning) monitoring, alarm and control systems are included in the smart home area. There are also other domains and environments in which the IoT can play a notable role and improve the quality of our life [4]. A number of entities are required that they connect to each other.

So, we need many signaling to operate monitoring and alarming system. The signaling cost is occurred for delivering information, data and messages. In this paper, we propose the architecture which applies the dynamic caching mechanism and reduce signaling cost in our alarming program system. The existing MQTT mechanism does not suitable in the current network situation because the IoT devices are growing exponentially. The dynamic caching mechanism performs the content distribution to the distributed caching servers automatically through the information. Also, there provide the enhanced alarm service and the network stability in the smart grid. The mobile station (MS) can be searched in low-layer caching server via minimum signaling and has lower network cost than the existing MQTT mechanism. In order to performance analysis, we compare proposed mechanism against existing MQTT mechanism.

This paper is organized as follows. In the section II, we introduce on MQTT and Alarm service. The section III is described as to the proposed alarming system's architecture by using dynamic caching mechanism. In section IV, we show the performance analysis and results are presented. Finally, we conclude this paper in Section V.

II. RELATED WORK

This section describes existing energy management system and MQTT. We research the alarm processing in the smart grid and focus on the MQTT.

A. Energy Management System (EMS) [5]

EMS have to provide advanced and various functions while keeping the easy installation and lower cost. The systems should apply with real life activities and practical feedback.

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There have some requirements for EM systems. Monitoring requires power consumption information at various temporal granularities. A client can receive near-real-time information with their power usage. Information integration is gathering a number of types of information like humidity, light, indoor temperature and client's history data. Intelligence and analytics is desirable function of system in new generation EMS. Most clients do not understand specific electrical system and have limited time to determine energy-related decisions. So, that function have to provide the intelligent actions such as balance energy consumption and consumer comfort. They can interact client and big data analytics to predict critical or useful situation.

B. Home Energy Management System [6]

HEMS centralizes the management of services and provides clients with comprehensive functions for power consumption information. They help households optimize their life patterns for reducing electricity fee such as scheduling the day-to-day power consumption. In addition to the home's appliances, HEMS is typically composed of three main elements:

An energy management gateway (EMG) operates a secure connection between the utility, the home's appliances and other electrical devices. This gateway provides an interface between the AMI and the home electricity infrastructure (appliances, generation, storage, and so on) and protect security between the AMI and the HEMS.

An energy management unit (EMU) gathers information about the status of appliances. This unit controls power consumption, electricity storage and generation in the home and communicates with the EMG to forward control commands or information from the utility to the home appliances. This energy control function provides the billing, status and calculation of power consumption.

C. Message Queue Telemetry Transport (MQTT) [4]

MQTT is aimed for connecting embedded devices and networks with applications and middleware. The connection operation uses a routing mechanism (one-to-one, one-to-many, many-to-many) and enables MQTT as an optimal connection protocol for the IoT and M2M.

MQTT is composed of three components with subscriber, publisher and broker. A device registers a subscriber for specific topics and inform the broker that publishers publish topics of interest. The publisher make event as a generator of interesting data. After making event, the publisher sends the information to the subscribers through the broker. Fig 1 shows the publish/subscribe process of MQTT.

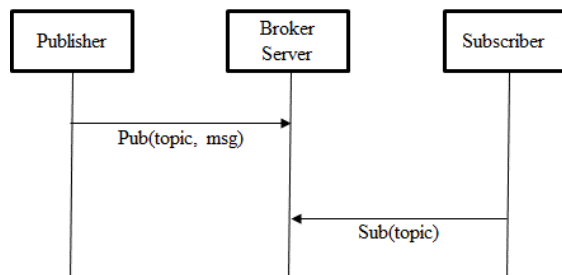


Figure 1. The publish/subscribe process of MQTT

MQTT operates the publisher/subscriber to provide transition flexibility and simplicity of implementation as depicted. MQTT is built on top of the TCP protocol. It sends messages through three levels of QoS.

Many applications can operate the MQTT such as alarm, health care, monitoring, energy meter and Facebook notification. Therefore, the MQTT protocol represents an ideal messaging protocol for the IoT and M2M communications and can provide routing for cheap, low power and low memory devices in the networks.

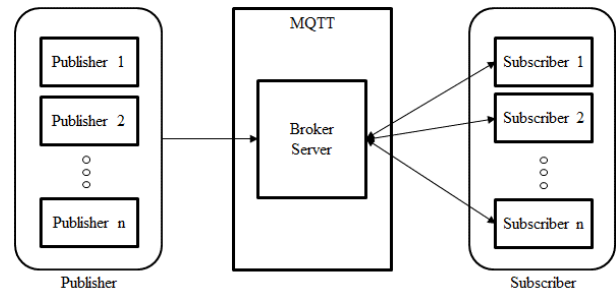


Figure 2. The architecture of MQTT

Fig. 2 shows the architecture of MQTT. The MQTT communication is shown as a hierarchical architecture. The alarm program's publisher (management server) which is a single server. So, we can think the hierarchical architecture to reduce signaling cost.

III. THE DYNAMIC CACHING ALARM SYSTEM (DCAS)

In this section, we describe the alarm program system and propose the hierarchical architecture for reducing the total signaling cost.

A. Alarm Program System Structure [7]

Each of the elements (DB, Broker, Management) can be implemented on a single server. The specific features of program are described in the Table1.

TABLE 1. The Specific Features of Elements

Element	Function
DB Server	▪ Collected history data management in the building ▪ Managing the information of the building and clients ▪ Saving the clustering value of Management Server
Management Server	▪ Analyzing the history data ▪ Requesting the alarm message ▪ Managing power consumption event
Broker Server	▪ Managing user topics ▪ Sending a message to a specific topic (building, Client)
Building	▪ Power consumption and control target
Client	▪ Subscribing topic messages from broker server ▪ Changing and peak control by using management policy

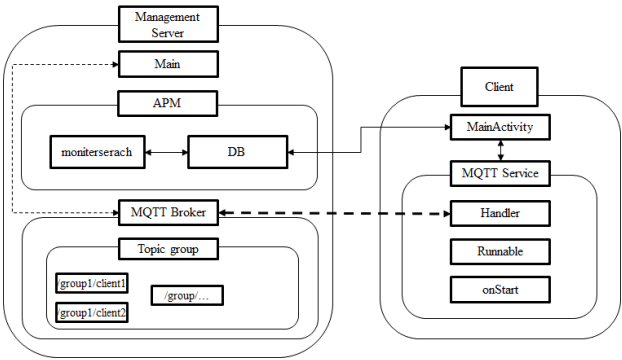


Figure 3. The structure of alarm program

Fig. 3 shows the structure of alarm program in the smart grid environment. The management server is composed of three components and interact many sensors in the building or home. The DB server stores history data from sensors and client power consumption. The management server provides information on power consumption and alarm message which are predicted from clustering algorithm. Since this paper propose the architecture for reducing signaling cost, the algorithm is omitted.

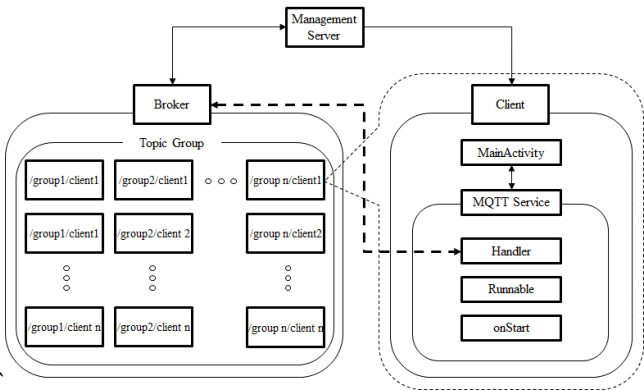


Figure 4. The s/w architecture of alarm system

The handler of client communicates MQTT broker server for receiving alarm messages. The broker server manages many topic groups such as hierarchical architecture in Fig. 4. So, we apply the hierarchical architecture by using caching mechanism.

B. Client [7]



Figure 5. The implementation pages of MS

The client can receive the notification from the broker server. The notification information is provided in text format. Further, the history data and prediction data are provided by the graph. Fig 5 shows the implementation pages of MS.

The management server uses history data and prediction data and notifies critical situation such as peak load. The push message can be saw through the MS screen.

C. The hierarchical architecture and each entity

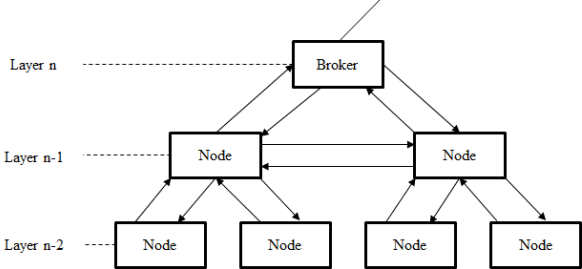


Figure 6. The hierarchical network architecture in proposed mechanism

Fig.6 shows the hierarchical architecture in proposed mechanism. The broker server is the broker server of management server. We do not limit node as a router, caching server, client and etc. The architecture is composed of tree structure. On the other hand, each distributed node supports not only the origin broker server but also another node as a temporary storage of data.

Generally, the node may be located where the connection density is high or the data request is tremendous. And, the tree level (that is, related to the number of caching server) is assumed with two or three levels according to the construction cost by network planner. The node states are divided into “possess”, “empty”, “update”, “service”. The possess is that a node possess the new data by generated from the client. The empty is that the node does not possess the new data. The “update” means that specific node distributes both new data and signaling message to low layer server or high layer server. Finally, the “service” means that the node provides the messages to caller.

D. The existing topic signaling procedure

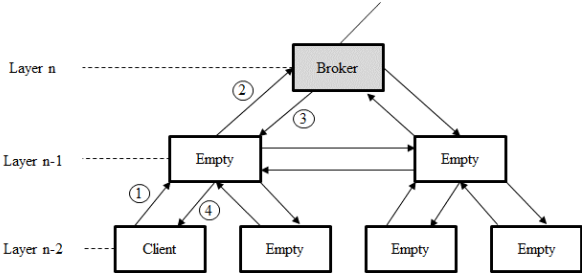


Figure 7. The existing topic signaling procedure

Fig. 7 shows the existing topic signaling procedure by requested from the client in tree architecture. If the distributed node does not have data, and if the broker server only has data,

the signaling procedure for data or messages request is progressed as Fig. 7.

E. The signaling procedure of proposed architecture

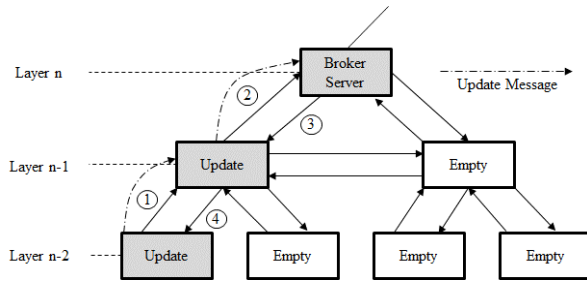


Figure 8. The signaling procedure of dynamic data update

Fig. 8 shows the signaling procedure of dynamic data update. And then, the broker server only distributes the requested data or alarm message to the distributed node which is close to client.

F. In case MS mobility

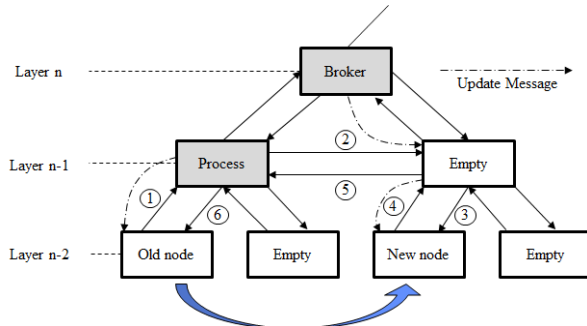


Figure 9. The signaling procedure in MS mobility

Fig.9 shows the signaling procedure in case client mobility. The client moves to another anchor node in hierarchical network architecture. If the data does not exist that the client moves to different node, the signaling is forwarded through the bypass route in mid-layer. Therefore, the number of total signaling is less than through broker server.

The client is provided on alarm message through old node during the saving times of new node. If the new node finish data updating in database, the client will provide service by node switching technology [8]-[9] for service continuity.

IV. PERFORMANCE ANALYSIS

In this section, we present the reduction of signaling cost by using dynamic caching mechanism in hierarchical architecture. The analysis evaluates a criterion as call hit ratio. We simplify assumption to obtain the signaling cost for analysing the proposed architecture. We simplify assumptions and it presents in detailed as follows [10]-[11].

- C : the cost of traversing any communication link except for wireless link
- C' : the cost of traversing any communication link for wireless link
- R : the cost of reading a database

- U : updating a data
- L : the levels of the tree
- Q : how far apart the two anchor point
- P : regional call-to-mobility ratio (RCMR)
- P' : call-to-data hit ratio (CC)
- Total signaling cost (SC) : used total network cost during caching or service

From the consideration above, we can calculate the equations as follows.

$$\text{Total signaling cost (SC)} = 1 + X$$

$$X = \frac{4U + 2L(C + C') - (P + P' - 1)(2L - 1)R}{(2Q + 1)U + 4(Q + P + P')(C + C') + (2Q + 1 + 3(P + P'))R}$$

These equations [11] can calculate the total signaling cost such as existing topic signaling procedure and dynamic caching. The total signaling cost in existing topic signaling procedure/dynamic caching mechanism. The dynamic caching mechanism is the proposed caching mechanism.

If the user mobility does not occur in Fig. 7, the factors of various caching mechanism set as following. The parameters of existing topic signaling procedure are $C = R = U = 1$, $C' = Q = P = 0$, $1 \leq P' \leq 10$. The parameter of proposed mechanism are $C = R = 1$, $C' = Q = P = 1$, $1 \leq P' \leq 10$, $U = 1$ or 0 .

If the user mobility is occurred in Fig. 9, the factors of caching mechanism set as following. The Parameters of existing topic signaling procedure are $C = R = U = Q = 1$, $C' = 0$, $1 \leq P' \leq 10$, $1 \leq P \leq 10$. The parameters of proposed mechanism are $C = R = Q = 1$, $C' = U = 0$, $1 \leq P' \leq 10$, $1 \leq P \leq 10$.

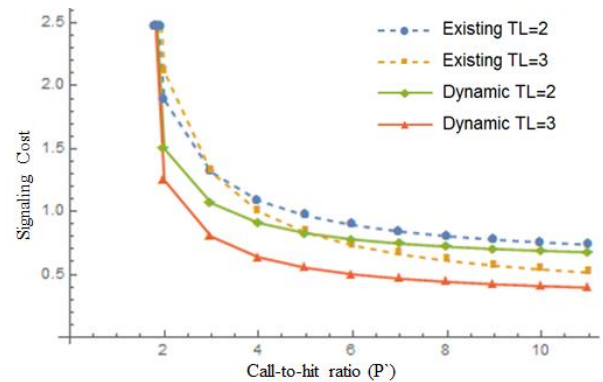


Figure 10. The signaling cost in non-user mobility

Fig. 10 shows the total signaling cost with the tree level in non-user mobility. The total signaling cost increase when tree level is high-layer because the architecture has a number of tree for updating nodes in hierarchical architecture. Also, proposed mechanism has the least cost compared with existing topic

mechanism because proposed mechanism does not occur frequently update of data by caller provide message.

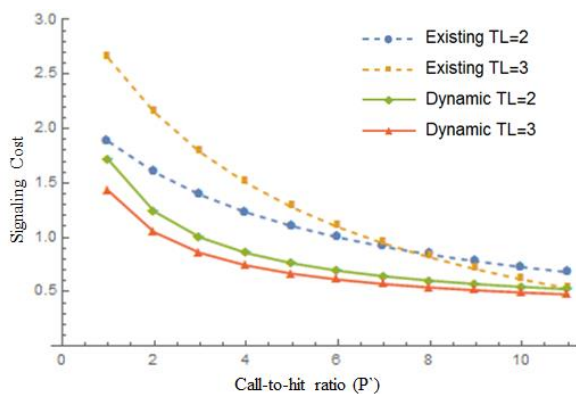


Figure 11. The signaling cost in user mobility

Fig. 11 shows the total signaling cost in user mobility. If the user mobility is occurred, the parameters of Q and P affect the total signaling cost. As a result, if the ratio of user mobility is increasing, the total signaling cost decrease. The data distributes effectively to new-caller and has shortest path for updating data. Also, the proposed mechanism has lower the signaling cost than existing topic mechanism.

V. CONCLUSIONS

This paper proposes the hierarchical architecture for reducing signaling cost in alarm system. In proposed mechanism, the broker server distributes data to close node from client and the client can search the corresponding data via minimum signaling. For the performance analysis, we compare proposed mechanism against existing topic mechanism. As a result, the proposed mechanism shows that the total signaling cost can be effectively reduced by using our mechanism. Therefore, the proposed mechanism is useful alarm service in the smart grid. In further study, we will study extended scale of smart grid environment.

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