Energy 93 (2015) 1385–1393

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Research on the data transmission optimization for building energy consumption monitoring system based on fuzzy self-adaptation method

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ARTICLE INFO

Article history:
Received 1 June 2015
Received in revised form
7 September 2015
Accepted 2 October 2015
Available online 6 November 2015

Keywords:
BECMP (Building energy consumption monitoring platform)
Data transmission optimization
VPI-FSaTC (varying packet interval fuzzy self-adaptive transmission controller)
VPS-FSaTC (varying packet size fuzzy self-adaptive transmission controller)
VPIS-FSaTC (varying packet interval & size fuzzy self-adaptive transmission controller)

ABSTRACT

BECMP (building energy consumption monitoring platform) offers powerful help to realize building energy conservation by collecting energy consumption data. A great quantity BECMPs have been established all over the world in recent years. However, packet loss problem begins to appear when the scale of BECMP is large enough and the network congestion happen. This paper presents a fuzzy control transmission methodology in order to solve the problem based on network delay. The proposed method could adjust the data transmission strategy according to the network congestion level by changing packet interval and packet size to adapt the changes of network load, and improve the quality and efficiency of data transmission. Three novel transmission controllers are proposed, VPI-FSaTC (varying packet interval fuzzy self-adaptive transmission controller), VPS-FSaTC (varying packet size fuzzy self-adaptive transmission controller), and VPIS-FSaTC (varying packet interval & size fuzzy self-adaptive transmission controller). The simulation results indicates that, the packet loss ratio decreases 23%, 71% and 79% by VPI-FSaTC, VPS-FSaTC and VPIS-FSaTC, respectively, compared to the default transmission method.

1. Introduction

In the last few decades, building energy consumption has experienced a significant increase. This trend is bound to continue in the future, so building energy conservation is one of the most important topics to alleviate energy supply shortage and reduce pollutant emission, realize the sustainable development of building energy and environment, with the objective of which is to increase the energy utilization efficiency and decrease energy consumption [1]. BECMP (building energy consumption monitoring platform) provides a powerful theoretical and technical support to promote building energy efficiency evaluation and energy-saving renovation, which has important practical and long-term significance [2–6].

There are lots of researches about how to develop a building energy consumption monitoring platform in recent years. In 2001, Mary et al. [7] from the U.S. Berkeley National Laboratory used PC (personal computer) as the collecting and storing devices to develop the system for monitoring and diagnosing the buildings' information. Their system releases the energy consumption data to the public via Internet and is the ancestor of the current system for monitoring buildings' energy consumption. In 2004, the Japanese scholar Nagata T [8] established the Internet-based platform for monitoring energy consumption among campus buildings. The NCT (network computing terminal) is used to monitor the electricity information. The energy consumption information can be displayed on the large display panel in real-time. In 2006, Wei Qingpeng et al. proposed to establish the energy consumption database for the large public buildings in Beijing and monitor the operating status of the key energy consumers via the sub-metering scheme; they developed the energy consumption sub-metering system for large public buildings [9]. In 2007, Bayindir et al. from Turkey [10] monitored the energy consumption in a teaching building within the campus. But their system just sent the data collected by the measuring instruments to PC via the RS485 bus, and supported neither network transmission nor data display. In 2009, Liu Yunjue

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http://dx.doi.org/10.1016/j.energy.2015.10.005
0360-5442/

et al. [11] detailed the purpose, mode, object and framework of the city-level system platform for monitoring energy consumptions among large public buildings. Their work is based on the energy consumption tests for the Shenzhen government buildings and other large public buildings. In 2010, Guo Chunyu et al. [12] proposed the framework of the energy consumption monitoring software platform and the approaches to the key technologies. They also described the actual development and application of the Beijing energy consumption monitoring system. In 2010, Jorge et al. from Portugal [13] proposed the platform for monitoring energy consumption among large public buildings. The terminal monitoring signals are sent to the data center servers via the RS485-Ethernet conversion module. The energy consumption data is delivered to relevant users of different departments in the form of spreadsheet via Email. In 2013, Manuel et al. [14] developed a campus energy consumption monitoring platform and monitored the electricity consumption among the 29 buildings in University of León, northwestern Spain. In 2014, Fernandes et al. [15] monitored the lighting energy consumption on the 6th, 11th and 20th floors of the New York Times Building (with a total of 52 floors). The results show that the lighting energy consumption on these three floors can be reduced by 25%, 29%, 29%, respectively, by lighting with sunshine, adjusting the light or changing behavior patterns.

In addition, some work has been done on monitoring energy consumption among house buildings. For example, in order to understand the difference between the predicted energy consumption and the actual energy consumption in the buildings, Filippin et al. [16–18] spent five years in monitoring energy consumptions of a two-floor house building in Salta, northwestern Argentina. In 2011, in order to understand how and when the energy is consumed in the room, Alahmad et al. [19] developed a visual 3D software platform, mapping each of sockets, air conditioners, lights and fans to the platform. A background database was also established to monitor each point in a polling manner. The returned energy consumption information is directly shown in the software platform in real-time. To save the costs associated with the measuring instruments, Ploennigs et al. [20] developed the heat balance equation-based virtual sensor to monitor and compute the heat consumption within the building. But difficulties arise when it is used to estimate the water and electricity consumptions.

The team of the author of this paper has studied the building energy consumption monitoring system since 2005 and monitored over 500 buildings in total. The project involves the energy consumption monitoring of a single building [21], the energy consumption monitoring of conservation-minded campus [22] and the energy consumption monitoring platform for large public buildings [6]. During the work, we found that the quality of network communication between the buildings and the data center servers has a big impact on the transmission of energy consumption data. The communication within a single building belongs to the LAN (local area network) communication characterized by high network transmission rate and data quality. The platform for monitoring energy consumption among Liaoning buildings spans a large area. The communication between the scattered buildings and the Liaoning Department of Construction involves various network carriers, such as China Netcom Group (CNC), China Mobile, China Telecom, and China Tietong. Consequently, the quality of network communication between the data collectors and the data center of Liaoning Department of Construction varies, directly degrading data transmission quality, especially when the platform operates on a long-term basis.

As we all know that, energy consumption data of BECMP plays an important role during the process of energy saving, which could not only be guidance for operation management, but also the basis of energy-saving diagnosis and evaluation of energy efficiency. However, how to ensure the data quality is a key issue for building energy conservation, especially for the large public buildings monitoring systems.

A fuzzy adaptive data transmission method is proposed in this paper to transmit the energy consumption data of buildings under poor network transmission conditions. The rest of the paper is organized as follows: Section 2 re-defines the network structure of the system for monitoring energy consumption of buildings from the perspective of the communication system, and further describes the actual difficulties in transmitting the energy consumption data from the large public building energy consumption monitoring system, as well as providing the solutions and ideas. Section 3 details the fuzzy adaptive data transmission scheme, including the fuzzy controllers based on the varying packet interval or the varying packet size. Section 4 carries out the simulations and Section 5 concludes the paper.

2. Problem description

2.1. System overview

From the perspective of communication and information, we re-partition the network structure of the energy consumption monitoring system for buildings. The typical communication system model is shown in Fig. 1, where the source, channel and destination are the indispensable components of the communication system.

Based on this structure, the abstraction of the energy consumption monitoring system for buildings is shown in Fig. 2. It can be illustrated as follows with the communication terms.

(1) Source: it consists of various measuring instruments and sensors at the perception layer, as shown in the outmost layer of Fig. 2, where E denotes the electric meter, W denotes the water meter, H denotes the heat meter, T denotes the temperature sensor, and F denotes the flow sensor.
(2) Channel: it mainly refers to the communication channel between the source and the destination, consisting of the underlying RS485 fieldbus and the network-layer Internet.
(3) Destination: it mainly refers to the data center server, as shown in the center of Fig. 2, where DC denotes the data center.

Smart gateways (i.e. the SG parts of Fig. 2) are the bridge between the source at the perception layer and the destination at the data center [23,24]. SG can serve as the destination of the perception layer sensors or the source of the dater center.

2.2. Transmission problem

The smart data collector or smart gateway is responsible for collecting energy consumption information from the underlying sensors and sending it to server at the data center periodically. The size of the energy consumption packet is dependent on the

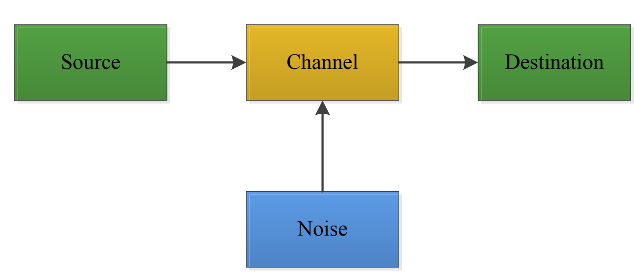

Fig. 1. Model of communication system.