Intelligent Meters for Improved System Operation and Customer Relationship Management

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Abstract-- **Since the time that electric power meters were introduced in the 1870s, the basic function of the meters has remained more or less unchanged. Many developed countries are still using the same technology that has existed for more than a century. In particular, meter readings for residential services are normally taken manually once a month or every two months. While automatic meter reading (AMR) has gradually been introduced in many places, the cost involves in retrofitting the existing systems may not be justified if they are used merely for meter reading. This paper proposes two approaches to enhance the functions of the meters intelligently thereby improving the operation of the electrical supply system and customer relationship management. Data mining (DM) techniques are first discussed for information extraction and an intelligent agent (IA) technique is also proposed for front-end customer services.**

Index Terms—**Automatic Meter Reading, Customer Relationship Management, Intelligent Agent, Customer services, Data mining.**

I. INTRODUCTION

SINCE the time that electric power meters were introduced in the 1870s, the basic function of the meters has remained more or less unchanged. The meters provide a record of the amount of energy being consumed and the customer are invoiced accordingly. Although electronic, computer and communication technologies have advanced greatly, many developed countries however are still using the same technology for residential electricity services that has existed for more than a century. Normally, meter readings are taken manually once a month or every two months. While automatic meter reading (AMR) has gradually been introduced in many places, the cost involves in retrofitting the existing systems may not be justified if they are used merely for meter reading.

From the operator's viewpoint, the existing situation should be improved because of the following reasons:

(a) To reduce the time lag between energy supply and actual revenue collection.
(b) To minimize the non-payment of bills by customers.
(c) To economize the costs and overheads incurred in meter reading, invoicing and revenue collection.
(d) To account for the differences between power generated and revenue collected due to energy losses and thefts.
(e) To improve the accuracy in meter reading and to eliminate possible mistakes in data entries.
(f) To obtain real-time information on the actual energy consumption by the end-users.
(g) To enable implementation of flexible or innovative tariffs."

While part of the above issues such as (a), (b), and (c) can be addressed by utilizing *Prepaid Meters*, the other problems are remained unsolved. In particular, updated and accurate information on the actual power consumption at the customer's side will be very useful for planning and operation. In particular, such information forms the basis for load management and planning.

On the other hand, from the customer's viewpoint, one of the main reasons for accepting any changes to the existing metering system must be based on much improved customer services. With the rapid advances in electronics, computer and information technology, a new generation of "intelligent meters" will provide solutions to the above issues. The new meters will be able to provide many additional services to the customers as well as gathering vital information for the utility companies. Coupled with the challenges of deregulation and increasing competition, the need for a new generation of power meter is imminent. The intelligent meter will change from a passive device to undertake a central role with endless potential. It will provide many options for the utility companies and the customers. In particular, the new meter will become the key to issues on

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system operations and customer relationship management (CRM). In this paper, a review of AMR functions is first given. This is followed by a discussion of two intelligent approaches in order to improve system operation and CRM:

- Use of Data mining techniques for knowledge extraction on load consumption and load management.
- Use of Intelligent agent techniques for front-end customer services.

II. Automatic Meter Reading (AMR)

The use of telephone or power line carrier (PLC) for controlling electrical energy utilization in homes and small businesses has been proposed in the late 80's [1]. The objective was to provide a personal computer (PC) based control and interface thereby giving the customer a greater degree of control. The philosophy was to shift some of the load from the peak to the valley and to enable reduction of the electricity charges. This was followed by a proposal on the use of CEBus for load management and AMR in the early 90's [2]. The concept was further extended to use radio links for both wake-up and return of data from a group of meters in a pipelined fashion [3].

Large-scale system implementation of Demand Side Management (DSM) and Distribution Automation (DA) has also been tested [4]. The issue has mainly been the need of a high performance communication system. On the other hand, a pilot installation in Rome and a number of major Italian urban areas has utilized MV and LV distribution for AMR [5]. It also included reading of other utilities such as gas, water and heating.

Outage Management Systems (OMS) are other implementations which incorporate Supervisory Control and Data Acquisition (SCADA), ARM, utility call centers, Customer Information Systems (CIS) and an automated mapping/facility management/ geographical information systems (AM/FM/GIS) [6]. Multi-service network for AMR has been introduced by Kansai Electric Power Co. (KEPCO) in Japan to provide supervision of consumption, load control and information services to customers. The communication network was shared with CATV companies and application of personal handyphone systems (PHS) [7].

A summary of technologies to enable the implementation of AMR and load management has been reported by Black and Ilic [8] in 2001. The paper provided a review of technologies and examples of manufactured products. Estimated costs were also given although it was understood that the costs vary greatly. The paper was intended to provide a general understanding of the potential for residential services. The potential services are:

(a) real-time pricing
(b) automatic billing
(c) home security
(d) outage notification
(e) remote connect/disconnect
(f) tamper alarm
(g) bundling with water and gas

While an extension of the paper [8] by Black & Ilic in order to provide a more comprehensive survey is warranted, this paper however serves to explore the utilization of other techniques to enhance the functions of the "intelligent meter". The two techniques are Data Mining (DM) and Intelligent Agent (IA). The functionalities of the intelligent meter are proposed as shown in Fig. 1.

The communication module provides interface with the data collector and the meter. The communication media can be RF, telephone, internet or power line carrier. The objective of the measurement module is to measure the amount of energy consumed and to record the quality of the power supply over the predefined period. The recorded information are stored in the database module where further processing will be carried out by the data mining module. The IA module provides a user-friendly interface. In this paper, only the last two modules are elaborated.

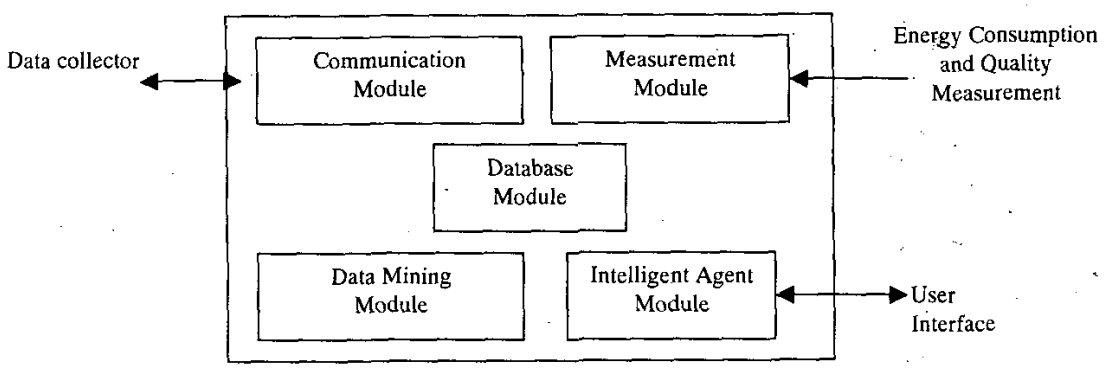

Fig. 1: Functional modules of Intelligent Meter

III. Data Mining (DM) Module

The term Data Mining (DM) is often used rather loosely. It was defined by Berry and Linoff [9] as *"Data mining is the process of exploration and analysis, by automatic or semi-automatic means, of large quantities of data in order to discover meaningful patterns and rules."* In order to extract meaningful new information from the data, six activities are identified by the same authors [10]:

(a) Classification
(b) Estimation
(c) Prediction
(d) Associate rules
(e) Clustering
(f) Description and visualisation

The first three activities are *directed* data mining with a goal to build a model to describe a particular variable with respect to the rest of the available data. The other activities are *undirected* data mining whereas the goal is to establish some form of relationship between the variables [10].

A. DM Techniques

DM techniques incorporate many approaches and computational algorithms from various disciplines such as operational research, statistics, artificial intelligence and computational intelligence. Example techniques are market basket analysis; memory-based reasoning; cluster reasoning; link analysis; decision trees and rules induction; artificial neural networks; genetic algorithms, fuzzy reasoning, automatic cluster detection etc [9-10]. One should take note that no single technique will satisfy all the goals and different goals call for different techniques. In the context of intelligent meters for improved customer services, the nature of the data and the goals must be identified.

B. Applications of Intelligent Meter

While AMR technologies are gaining maturity and acceptance from the utility companies and the customers, the proposed intelligent meter should possess additional features than merely recording the amount of energy consumed. One of the reasons that AMR is not yet widely applied at present is the large amount of data involved and the communication requirements. Although communication technologies utilizing power line carrier, telephone, radio, internet, satellite are all technically feasible, to collect and to process the large amount of data will require substantial communication infrastructure and high performance computing platforms. The problem on communication requirements is generally solved by the incorporation of optical fiber in conjunction with the power cables. The processing of data can either be carried out at a centralized location or at distributed terminals. The proposal in this paper is to deploy DM techniques at the meters and only relevant information is uploaded as requested. The intelligent meter serves as the local data collector and warehouse. Knowledge extraction and data processing are performed utilizing various DM techniques at the user's site. Such information will be readily available to both the user and the utility company. Hence, the communication requirements are reduced and the information will improve the following system operations greatly:

(a) energy monitoring and analysis
(b) shedding and transfer of load
(c) profiling and balancing of load
(d) detection of outage, tampering and theft
(e) detection of failure and outage notification
(f) network management, analysis and modeling
(g) network diagnosis and analysis
(h) profiling of customer use pattern
(i) flexible tariff to encourage load management by customer

The list is by no means exhaustive and many additional benefits can be achieved by the intelligent meter incorporating DM techniques.

IV. Intelligent Agent (IA) Interface

While the Intelligent Meter is capable to perform many data processing and knowledge acquisition tasks in the background, a new approach can also be adopted to provide a next generation customer service on the front-end. An example is to deploy an IA system to interact with the user's enquiries. An example is the Artificial Intelligent Neural-network Identity (AINI) system, which is under development by researchers at Multimedia University, Malaysia [11]. The system may assist the customers to search and locate information from the meter and within the entity of the utility company. The aim is to provide interface as accurately, quickly and in the most natural manner possible. The system enables the users to either key in questions, or use voice activation methods to query the system. In return, the system will return the answers in either voice or text. In addition to the search of information, the system may behave and engage in conversations with human-like reactions. The system acts as an intelligent service provider which looks for the particular type of information for the user in the most effective and natural manner.

This technology aims to reduce users' reliance on live agents by using artificial intelligence (AI) to provide better answers to service inquiries. The system uses natural language parsing i.e. AIML (Artificial Intelligent Markup Language) and AINI engine [12] to search the application's own knowledge base as well as other enterprise data sources connected to the system and return appropriate responses to inquiries using *chatterbot* – an agent based automatic interaction system. The knowledge represented in the patterns is represented in an XML specification called AIML. The AINI architecture can be conceptually subdivided into two main components. The Front-End is the client side and Back-End is the server side.

The tasks to be performed at the front-end are:

(a) Preprocessing of user's enquiry, and
(b) Postprocessing of output reaching out to the user.

At the back-end, the core modules included:

(a) An AINI engine processes user input based on knowledge base,
(b) a Natural Language Processing (NLP) Language analysis controller,
(c) a semantic/discourse controller influencing the decision-making process and interaction with the user,
(d) an animation controller supporting interactive animated characters,
(e) a speech controller providing text-to-speech conversion,
(f) a knowledge base consisting of AINI's knowledge base, customer service knowledge base and an expression/emotion template database.

At the current time, the AINI system is still being tested. A general analysis of the chat log of the system has shown that users find the system very friendly and treats the agent as a real life entity. Users are also generally able to retrieve the required information faster and more accurately. An example of the dialogue is shown in Fig. 2.

User: Good Day
Agent: **[Alert, Greet: Straightens and raises eyebrows then bows]** Likewise. How are you today?

User: *I have a big problem!*
Agent: **[Surprised: Agent look surprised.]** Yeah? How can I help you?

User: I am looking for an air ticket from Kuala Lumpur to London tonight! Where is the fastest place I can book a ticket through MAS?
Agent: **[Read, Explain]** Easy my friend! The fastest way you can get your ticket is from any Maybank ATM counter.

User: How to use the ATM counter machine?
Agent: It's easy, even my mother know how to use it! I am now loading the page for you. *[Loading the payment page for MAS at http://www.mas.com.my/travel_assistant/main.html]*

User: Wow, you are a great assistant!
Agent: **[Pleased and smile]** My pleasure. Glad to help out.

User: Thank you for everything.
Agent: **[Pleased and smile]** You are most welcome.

User: I must be going now.
Agent: **[Sad and Curious]** Right now? Well, it is nice meeting you. Don't forget to drop by some other time.

User: Very nice chatting to you as well
Agent: **[Smile and Pleased]** Yes. I enjoyed our conversation.

User: Bye.
Agent: **[Wave and Pleased]** See you later.

Fig. 2: An example of chat log conversation

V. CONCLUSION

This paper has proposed two enhanced features for an intelligent meter to be used for residential electricity services. While AMR is gaining maturity and acceptance, it is suggested that additional functions are required to improve system operation and customer relationship. In addition to the basic functions normally found in automatic meters, two modules based on data mining and intelligent agent are discussed. The objective is to apply DM techniques to perform high level knowledge extraction and information processing. This will reduce the communication overhead between the meter and the collection points. Another suggestion is to employ IA for customer interface. The AINI system is introduced which can be easily adopted for this proposal.

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VII. BIOGRAPHIES

Dr Lance Chun Che Fung graduated from the Hong Kong Polytechnic in 1974 with a Certificate in Maritime Electronics. Subsequently, he received a Diploma and an Advanced Diploma from the Brunel Technical College, Bristol in 1976; a Bachelor of Science degree (Maritime Technology) with First Class Honors and a Master of Engineering degree (System Test Technology) from the University of Wales, Institute of Science and Technology in 1981 and 1982 respectively. In 1994, he received his Doctoral degree from the University of Western Australia and in 2000, he received a Graduate Diploma in Business Administration from the Curtin University of Technology. He has lectured at the Singapore Polytechnic from 1982 to 1988. Since 1989, he joined the School of Electrical and Computer Engineering at Curtin University of Technology, Perth. He is currently a Senior Lecturer in the Department of Computer Engineering. His research interests include intelligent systems applications, optimization techniques, instrumentation, internet and IT applications.

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Dr Terence Law received his Doctorate degree in Electrical Engineering from the University of Western Australia in 2000. In 1979 he received a Master of Science from UMIST in the UK. From 1979 to 1987 he worked in the Planning Department of the China Light and Power Company in Hong Kong and was mainly involved in transmission planning activities. In 1988, he joined Western Power in Western Australia and has been responsible for various transmission system planning activities including design and planning of the transmission systems, investigation of power system problems, analysis of power system behaviour and development of power system planning and analysis tools.