COMMUNICATION DEMAND MODEL IN CENTRALIZED MEASUREMENT SYSTEMS

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Abstract: The present work is a study of communication demand in centralized measurement systems. The study is based on a probabilistic consumption model and an architecture where a single communication server, typically located in a data concentrator, must provide communication for several pairs meter/display.
We conclude that, for typical consumers (200kWh/month) and a specific architecture (one communication interface serving 10 pairs meter/display) an event of several (more than five) simultaneous communication requests is very rare. We also describe a criteria that maximizes the number of retransmissions of each message within a maximum "time to live"; such policy is important when the communication channel is unidirectional and there is no communication confirmation.

Keywords: consumption models, communication demand, centralized measurement systems.

1. INTRODUCTION

Recently, a series of advances in the electrical energy measurement have been observed. Such advances are typically characterized by the inclusion of data processing and transmission functionalities in the meters.

In the present paper we consider a communication problem that arises in a specific distribution scenario where several meters are located in a box and a unique communication server that must transmit the measurement information of such meters to remote displays located on the consumer house[1-5]. We investigate which should be the communication server performance in order to achieve a reasonable maximum delay in the information refresh on the consumer display, considering typical Brazilian consumption profiles. Simulation results show that for typical consumers with 200kWh/month and architecture where a communication interface serves 10 pairs meter/display, the probability of an event where more than 50% of the meters simultaneously request the refresh of their displays is 0,01%. The results are discussed in details in Section 2.

We also consider the problem of display refresh in a scenario where no acknowledge of receipt can be send from display to meter - a typical scenario in Brazil - and one wants to maximize the number of retransmissions within a maximum allowable delay. We describe an algorithm that, given a sequence of refresh requests, determine the best sequence of transmissions in the sense the number of transmissions is maximized for each meter. Such results are described in Section 3.

2. CONSUMPTION MODEL

A technical problem that frequently occurs in the structure of distributed systems for electrical energy measurement is the delay to refresh the consumer displays in a case of high demand for communication in the system. This event occurs due simultaneously refresh of several consumer displays. Typically the displays are refreshed only on increase in consumption of 1 kWh. A technical rule on electricity metering defines the maximum delay of 1 minute to refresh the consumer displays.

Additionally, for a common meter's architecture, there is no multi-task processing. That implies in a sequence of individuals displays refresh when at least two meters increase theirs consumer by 1 kWh. In this case, if the average delay to refresh an individual display is 10 seconds, the delay to refresh 7 or more displays will exceed the limit (60 seconds) defined by the technical rule.

To study the frequency of simultaneous refresh of several meters we create a statistical model and implemented computer simulations for consumption demand.

We consider two cases: a typical consumer with the daily average consumption curve [6] and an extreme consumption demand of 2,4 kW (corresponding to maximum current supported by the meters)

2.1 Statistical Model

In this model we consider the time range of greater consumption, since it has a higher probability of simultaneous refresh. This range includes begins at 5 p.m. and finishes at 11 p.m. and the average consumption is close to 0.6 kW.

During this period about of 3.6 kWh are consumed and a consumer display refreshed about 4 times. Considering the probability of the 1 kWh increase as homogeneous on this time range, the probability of refresh a display in a given second is $p = 1.1 \times 10^{-2}$.

Considering a distributed measuring system with 12 meters and the consumers connected to them as independents, the probability of n meters refresh simultaneously is:

$$P(n) = \binom{12}{n} p^n * (1-p)^{(12-n)}$$

where, $\binom{12}{n}$ is the binomial coefficient.

Table 1 shows the probability *P (n)* of n meters refresh and conditional probability *P (n | n>1)* since there was at least one remote display refresh:

TABLE 1

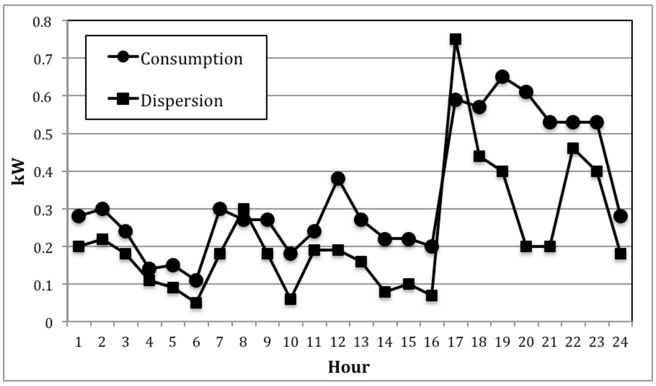
n	P(n)	P(n|n>1)
0	0,60	-
1	0,31	0,78
2	7,5E-02	0,19
3	1,1E-02	2,7E-02
4	1,1E-03	2,7E-03
5	7,4E-05	1,9E-04
6	3,8E-06	9,4E-06
7	1,4E-07	3,5E-07
8	3,8E-09	9,5E-09
9	7,3E-11	1,8E-10
10	9,6E-13	2,4E-12
11	7,6E-15	1,9E-14
12	2,7E-17	6,9E-17

Therefore, the probability of 7 or more simultaneous displays refresh, at a given second, is P (n> 7) = 1.58×10^{-11}. Thus, the probability of this event occurs on a month is 1.7×10^{-10}.

We also calculate the probability of simultaneous refresh of at least seven displays at a extreme consumption of 2.4 kW. In this case, on a month, we have P (n> 7) = 1.5×10^{-3}.

2.2 Computational Simulation

In [6] Francisquini presents load curves estimation in a daily basis for consumers connected to low-voltage power distribution networks. Figure 1 shows the load curve estimation for typical consumers with about 200kWh/month. We use this curve to simulate the hourly average consumption of 12 consumers. And consider that at each hour the consumption is given by a Gaussian distribution with average and dispersion shown in curve of Figure 1.



The consumption at each second is calculated from a Gaussian distribution with average equals to 1/360 times the hour average consumption and dispersion equal to 5% of the average. We start the simulation with the meters consumptionequal to zero and increment, at each second, theirs consumption according the algorithm above.

For a set of 10,000 independent simulations, we obtained the probability P (n) of n simultaneous displays refresh:

TABLE 2

n	P(n)	P(n|n>1)
0	0,77	-
1	0,19	0,86
2	0,03	0,13
3	2,9E-03	0,01
4	2,0E-04	9,1E-04
5	1,0E-05	4,4E-05
6	5,8E-07	2,6E-06
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0

We also simulate the system with an extreme consumption, 2.4 kW.

3. ALGORITHM FOR COMMUNICATION SERVICE

In the previous section, we showed that, in typical centralized measurement systems, the coincidence of several refresh requests is a very infrequent event. In most of these systems, however, the communication channel is unidirectional, in such a way that there is no confirmation of receipt from display to meter. Hence, if possible, one would like to send the refresh messages for each display - as long as these messages are sent within a maximum "allowable delay" (in Brazil, regulation admits a maximum delay of 60 seconds).

We describe a simple algorithm that determines, given a sequence of requests, which is the best service policy, in the number of transmissions of each refresh message is maximized. We give mathematical formalization of the problem next:

PROBLEM: Maximum retransmission problem

INPUT: integer k, pairs of integers (x_1, y_1), ..., (x_n, y_n) such that $y_i \geq T$, $T = 1, ..., n$ (each pair contains the number of services, that is, transmissions, given to a message and the number of units of time that this message has before it is discarded, called time to live)

OUTPUT: YES if and only if there exists a function f : {0, ..., max{ti} + T } → {1, ..., n} such that

- $f(t)=i \leftrightarrow t \leq y_i$; and;
- $\forall i=1,...,n, x_i + |Im^{-1}(i)| \geq k$,

where Im^{-1} (i) denotes the preimage of i by f.

We claim that, for each fixed desired number of retransmissions *k*, a simple algorithm determines whether *k* transmissions can be guaranteed for each message. The algorithm is based on the fact (stated without proof because of limit constrains) that the best criterion is to retransmit the "oldest" message that was not yet transmitted $\underline{k}$ times. Hence, an optimization algorithm can be obtained by testing the above criteria for increasing values of k and to determine the largest one for which the criterion works.

REFERENCES

[1] *Inmetro regulation 371/2007.*

[2] *Inmetro regulation 11/2009.*

[3] C. J. Bandim, F. C. Luiz, F. C. Souza, J. E. R. Alves Jr., J. C. R. Santos, L. C. G. Britto. "Sistema eletrônico de monitoração individualizada de consumos e método de monitoramento individualizado de consumos em um sistema de medição centralizada," Brazilian Patent PI0703417-2 A2, Mar. 3, 2009.

[4] R. S. Costa, L. M. Alvarenga, R. P. Caldas, A. V. Pinto Jr., J. C. G. Pimentel, C. J. Bandim, F. C. Souza. "Sistema eletrônico de monitoração individualizada de consumos e método de monitoramento individualizado de consumos em um sistema de medição centralizada," US Patent 5 831 550, Nov. 3, 1998.

[5] R. Vidinich. "Furto de Energia e suas conseqüências," In *VII Encontro Nacional de Conselhos de Consumidores de Energia Elétrica*, 2005

[6] A. A. Francisquini, Estimação de Curvas de Carga em Pontos de Consumo e em Transformadores de Distribuição, Tese de Mestrado, 2006