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The effect of pre-coding error on Cooperative Wireless Transmission in smart Neighbor Area Network

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Abstract

Smart Grid Network (SGN) has recently received a great deal of attention and attracted a considerable amount of research. In fact, (SGN) becomes an alternative source of power since it provides efficiency and reliability power consumption. Thus, SG architecture includes several communication schemes to ensure the best transmission of power and satisfy the consumer's requirement. To reach these ambitions, the transmission must be established at time and without error. In the traditional transmission, every consumer transmits the power demand using a TDMA mechanism which prolongs the delay. In this paper, the purpose is to suggest a model that can quickly transmit the power demand and achieve a good performance in terms of delay .The scheme is called Cooperative Wireless Transmission for Smart Neighbor Area Network (CWT). The cooperative means that all consumers can participate and coordinate between them to transmit the total power. So, the first purpose is to gather the total power of all consumers simultaneously and rapidly by employing QPSK modulation so that to improve the throughput, the second one is to evaluate the performance of CWT in terms of Cooperative Symbol Error Rate (CSER) and Estimated Power (EP). All results are presented using numerical simulations

Keywords: Smart Grid; Cooperative Wireless Communication; Power Supply; CSER; Smart Neighbor Area;

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1. Introduction

Nowadays, the electrical power has grown rapidly and thedemand increases highly. The amount of power must always beprovided to meet the varying demand. A disproportion on thepower supply will damage the stability and the quality of power.So, to maintain the stability of the grid, the Smart Grid is thekey architecture to adjust the capacity and distribution of theelectricity. SG is a modern electric power-grid infrastructure thatuses information technology to optimize the production of thepower. One of the important elements in smart grid architectureis the Demand Response Management (DRM) which aims tomanage the energy and satisfy the consumer's requirements. Tosatisfy these constraints and reach a good load-balancing, theCWT scheme requires the aspect of the very Short Term load(VSTLF). The VSTLF consists of the estimation of the powerahead to prepare the production. In this context, to implementthis architecture, SG network must be able to operate under theerror of some of its components so that the impact of this failureon the performance of the electrical grid is minimized [1].

In the SG network, there are two types of communications: oneis the communication between various kinds of appliances suchas sensors, home automation, lighting system and the dedicated smart meter. Another one is the communication between smartmeters to smart grid infrastructure, which could be either wirelessor wired. Wireless communications such us cellular networks and wireless mesh networks can be used to connect the consumerto the operator [2]. It can offer a significant improvement forthe smart grid network. Nevertheless, wireless transmissions areerror-prone and transmission errors which can lead to a mismatch on the power supply information exchange [3]. As an alternative solution to overcome these challenges of practical environments,the cooperative transmission techniques have been used so that toimprove the reliability of wireless links and assure the efficiencyof power supply information.

Many researchers have been presented in the field of cooperativewireless transmission. In fact, a particularly interesting proposalarchitecture has been proposed in [4] by employing mesh cooperativecommunication. The main objective in [5] is to improve theperformance of Wireless Mesh Networks (LWMN), a cooperativecommunication for smart grid have been suggested to improvethroughput, and energy efficiency, packet delay..

Firstly, the cooperative wireless scheme that we propose make the transmission simultaneously compared to TDMA. Secondly, it can offer a good time and decreases the delay under channel error, also when multiple users transmit their power supply, we are certainly interested to proceed the total of the power not only for one consumer. So, this paper investigates the analysis of the proposed CWT in terms of Cooperative Symbol Error Rate (CSER), furthermore, an evaluation in term of Estimated Power (EP) is established. Then, this paper is organized as follows. Section II describes the model of system. Section III, we introduce the Cooperative Wireless Transmission with QPSK modulation by considering the channel error. In section III, Simulationresults are presented and discussed. A conclusion of this paper is given in Section IV.

2. System Model

The system model under consideration is shown in Fig. 1.N consumers are selected to forward their power supply. Thesmart home contains smart appliances, and these appliances areconnected to one smart meter (SM) that gathers the informationabout the needed power in the entire house to the Data AggregationPoint (DAP) via wireless link. The DAP transmits periodicallythe meter data collected from the consumers of Neighbor AreaNetwork (NAN) to the Control Center (CC).

The noise uncertainty, multi-path fading and shadowing whichare characteristics of practical wireless transmission causes timedelay and degrades the transmission. Thus, the information aboutpower supply is affected which is intolerable in smart gridenvironment. For the model of channel, we chose the Rayleigh fading.

For every link, the received signal is then given by:

$$y = x_i h_i + n \tag{1}$$

wherex_i represents the power demand for one consumer. n is acomplex zero-mean white Gaussian random process with σ_n^2. Thefading coefficients hi are zero-mean complex Gaussian randomvariables.

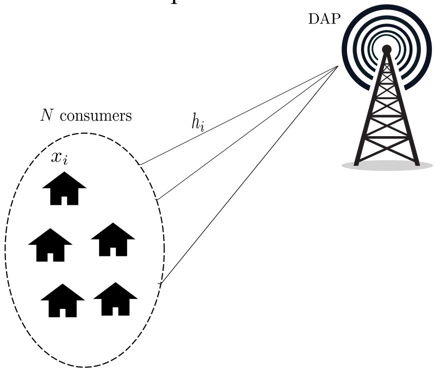

Fig 1.System Model

3. Cooperative wireless transmission for Smart Neighbor Area Network

The Cooperative Wireless Transmission of Smart Meteringcalled (CWT) is proposed to improve the transmission qualityby reducing transmission errors and time delays. The aim is tocooperate between all users to convey the total power supplywith the rapidly and simultaneously mechanism called CWT. Thequadrature phase shift keying (QPSK) modulation is used, which is advantageous in terms of throughput and bandwidth efficiency.In the traditional mechanism using TDMA, each consumertransmits in rapid succession, one after the other. In the cooperativescheme that we propose, the first time slot (0) is allocated to thecontrol center to broadcast the pilot symbols, only one time, toall users for the estimation of the channel state information (CSI).After that, all the consumers start transmitting their data dependingon the synchronization process [6]. At the transmission, weadopt a pre-coding technique in order to avoid interference andattenuation of power signal. In addition to that, we assume that the complex fading channel coefficients are estimated at thepre-coding levels with errors. So, from (1), the received signal isequals to:

$$y = \sum_{i=1}^{N} \frac{x_i \hat{h}_i^*}{\|\hat{h}_i\|^2} h_i x_i + n \tag{2}$$

Let the true channel be $h$and the estimated channel be$\hat{h}$, then h and $\hat{h}$ are related by:

$$\hat{h} = h + e \tag{3}$$

What leads us to:

$$y = \sum_{i=1}^{N} \frac{h_i^* + e_i^*}{\|h_i + e_i\|^2} h_i x_i + n \quad (4)$$

So, we have:

$$y = \sum_{i=1}^{N} \frac{h_i^* h_i}{\|h_i+e_i\|^2} x_i + \sum_{i=1}^{N} \frac{h_i^* e_i}{\|h_i+e_i\|^2} x_i + n \quad (5)$$

Where refers to the sum of symbols modulated with the QPSK modulation, the channel coefficients h_i is supposed to be independent and distributed as $\mathrm{CN}(0,\sigma_h)$. The additive noise nis also distributed as $\mathrm{CN}(0,\sigma^2)$, and e is the channel estimation errors which is distributed as $\mathrm{CN}(0,\sigma_e^2)$ where σ_e^2=E[$|\hat{h}|^2$]-E[$|h|^2$]. Therefore, $h_i$is also distributed as $\mathrm{CN}(0,\sigma_h+\sigma_e^2)$

For simplicity, we assume that $h_i+e_i \approx h_i$so the received signal can be expressed as:

$$y = \sum_{i=1}^{N} x_i + \sum_{i=1}^{N} \frac{h_i^* e_i}{\|h_i\|^2} x_i + n \quad (6)$$

The projection of the complex term into the real axis leads us to :

$$y_r = \sum_{i=1}^{N} x_i + \sum_{i=1}^{N} \frac{h_i^r e_i^r + h_i^I e_i^I}{\|h_i\|^2} x_i + n_r \quad (7)$$

The received signal can be decomposed into the message part $\sum_{i=1}^{N} x_i$, the noise and error part$\sum_{i=1}^{N} \frac{h_i^r e_i^r + h_i^I e_i^I}{\|h_i\|^2} x_i + n_r$.

For the rest, we put : $v_k = \sum_{i=1}^{N} x_i$

4. Estimated Power

In this subsection, the process of treatment of the Total EstimatedPower (EP) is given. Each SM contains the informationabout the value of the power in each home. We denote theconsumption power of all appliances in each house i by P_i. The received power at the level of the CC is given by: Pt=[P1……PN], the power Pi is sent according to an analog operation. First, we applied an equalization of 2^8 levels and a step p_u on $P_i$to get a determined number of the power to transmit. After that, we proceeded with the coding of thequandization levels to get the binary vectors. Also, we modulated each bi with a quadrature phase shift keying (QPSK).

At the reception, since we transmit the total of power, we get a combination of the transmitted QPSK bits which depends on the number of N. For instance, if N consumers transmit at the same time, v_k will take the following value: N, N+jN, jN,-N-jN,-jN,-N as given in Fig. 2 for two consumers. Thus, v_k are non-equiprobable, a Decision Boundaries D_k is required to make a decision based on the hyperplane separation.

The D_k is calculated for the real and imaginary part, where k is the position of the symbol. The Forumla of $D_k$is given as,

$$D_k = \frac{d}{2} + \frac{(\sigma_n^2 + \sigma_t^2)\ln\left(p(v_k)/p(v_{k+1})\right)}{d}$$

After all this process , we calculate the estimated power (EP) based on the step of quantization. So, the expression of (EP) is

$$EP = \sum_{j=1}^{8} \frac{v_k+N}{2} 2^{j-1} p_u \qquad (8)$$

Where p_u is the step of quantization.

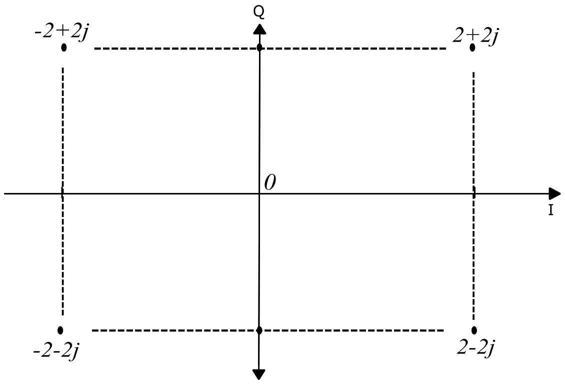

Fig 2.Received Value for CWT scheme

5. Probability of error

In this subsection, we evaluate the performance of CWT byusing QPSK modulation. For this, we calculate the probabilityof error for the total received value. It is noted that all thesevalues are non-equibrobale. First, we look the area when thereceived value is decoded correctly. After that, we calculate thetotal probability of all received value.

Assuming that the additive noise n follows the Gaussian probability distribution function. For instance and from Fig. 2, we consider for example $v_1 = 2 + 2j$. The v_1 is decoded correctly only if yfalls in the area of:

$$P(y|v_1) = P(\Re_y > D_k|v_1)P(\Im_y > D_k|v_1) \qquad (9)$$

Where $P(y|v_1)$is the conditional probability distribution function (PDF) of y given that v_1 was transmitted. By projection of (9) on the real and imaginary parts, Theprobability of v_1 being decoded correctly is

$$P(\Re_y > D_k|v_1) = P(\Im_y > D_k|v_1) = Q\left(\frac{D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) \qquad (10)$$

Where σ_t refers to the total noise power for the error part, which is equals to

: $\sigma_t = \sigma_e^2 \times E\left(\sum_{i=1}^{N} \frac{h_i^r + h_i^I}{\|h_i\|^2}\right)^2 \times E(x_i^2) v_k = x + jy$.

For the intermediate value, the probability is calculated on the left and the right of the value. In fact, Let put $v_k = x + jy$where x and yare respectively the coordinates of $v_k$on the real and imaginary axis. The procedure of decoding correctly (PD) as follows, At the reception, if we get $(x > 0, jy = 0)$, the PD is :

$$P(y|v_k) = Q\left(\frac{D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right)$$

$$P(D_{k-1} < \Re_y < D_k|v_k) = P(d - D_k < \Re_y < D_k|v_k) = Q\left(\frac{d - D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) + (1 - Q\left(\frac{D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) \quad (11)$$

Where d is the distance between two symbols.From (9), (11) then we obtain:

$$P(y|v_k) = Q\left(\frac{D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) . \left[Q\left(\frac{d - D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right)\right. \quad (12)$$

Based on the same analysis, for $(x = 0, jy > 0)$, the PD isthe same as calculated from (12).If the number of users is even, a term depending on $v_k = 0$ iscalculated as:

$$P(d - D_{k-1} < \Re_{y0} < D_{k|v_k}) = P(d - D_{k-1} < \Im_{y0} < D_{k|v_k}) = Q\left(\frac{d - D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) + \left(1 - Q\left(\frac{D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right)\right) \quad (13)$$

Using the equation from (11), (9), we have computed the errorprobability of CWT scheme. It defined as:

$$CSER = 1 - \sum_{i=-N}^{i=N} p(v_k). P(y|v_k) \quad (14)$$

where CSER refers to the Cooperative Symbol Error Rate. It defined as the error rate of the received sum of modulated symbols. $P(v_k)$ is the probability of v_k received value which equals to:

$$p(v_k) = \frac{C_N^{N-K/2}}{2^N} = \frac{N!}{(N - i/2)!\,(N + K/2)!} \quad (15)$$

For instance, even if the number of consumers, the total error probability is then equals to :

$$\begin{aligned} CSER = 1 - \sum_{i=-N}^{N} 2 \cdot p(v_k) \cdot Q\left(\frac{D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) \cdot \left(1 - Q\left(\frac{D_k}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right)\right) \\ +4 \cdot p(v_i) \cdot Q\left(\frac{D_i}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) \cdot \left[Q\left(\frac{d - D_i}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) + (1 - Q\left(\frac{D_N}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right)\right] \\ +2 \cdot p(v_N) \cdot Q^2\left(\frac{D_N}{\sqrt{\sigma_n^2 + \sigma_t^2}}\right) \end{aligned} \quad (16)$$

Theoretical results are also compared and verified by simulation on the next section.

6. Simulation Results:

In this section, we investigate the performance of CWT scheme by employing QPSK modulation . We consider a smart neighbor with two consumers just to simplify, our main is to collect the total power of all consumers. We analyze the proposed system by taking in the consideration that the transmission is imperfect at thePre-coding side. We calculate the theoretical values of CSER by using the function qfunc in Matlab software to compare the theoretical with simulation results. For the purpose of evaluation, the board I, presents the power supply of two consumers, every hour, we collect their power supply.

The obtained results shows that CWT performance are close to TDMA as shown on Fig 3, meaning that even if the number of users increases, the transmission is simultaneous and don't make delay which is necessary in SGN environment, then, the performance of CWT still satisfying despite of considering the error. To more evaluate our system, we plot the estimated power (EP) with different value of Signal to Noise (SNR).In Fig. 4, when the SNR equals to 8dB, the received power has some fluctuation, and so, an average technique is done to improve the (EP). So, the received power is still close to the transmitted one. This means that CWT scheme improves the reliability of transmission and reduces power losses instead of taking the modulation and error into account.

Table 1. Power Supply for two consumers

Time	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
User1	7,798	7,757	7,745	7,761	7,743	7,781	7,783	7,768	7,74	7,613	7,598	7,617	8,326	8,509	8,544
User2	9,415	9,633	9,696	9,813	10,079	10,343	10,804	11,10	11,341	11,579	12,005	11,940	12,060	12,036	12,106

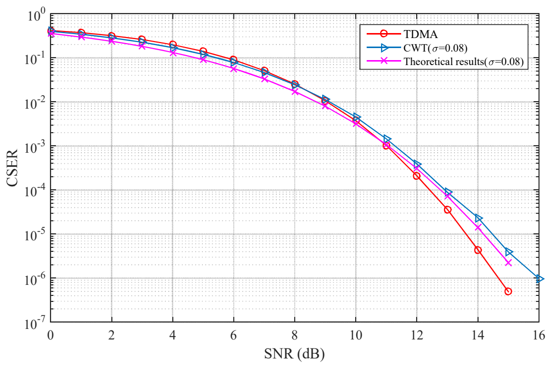

Fig 3.Average CSER of The cooperative transmission with QPSK modulation,and $\sigma_e = 0.08$

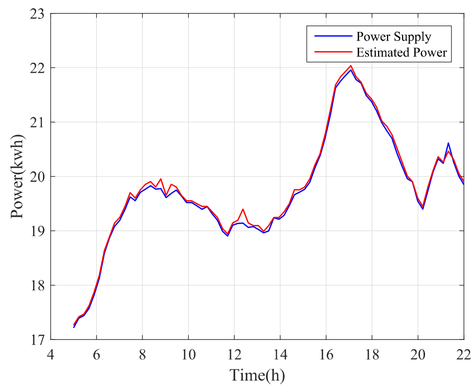

Fig 4.Comparison between transmitted and received Power for an SNR=8dB, and $\sigma_e = 0.08$

7. Conclusion

In this paper, The performance of Cooperative Wireless Transmissionfor Neighbor Aera Network with QPSK modulation under channel error hasbeen investigated. The purpose is to estimate the total power of all consumers by using CWT scheme.Moreover,The exact expression of CSER has been determined. Thus, in various value of sigma error, our approach has been verified to acquire the best performance for Estimated Power(EP). The future work aims to analyse the performance of CWT scheme on the unsynchronized case

References

[1] D. Niyato and E. Hossain, "*Reliability analysis and redundancy design of smart grid wireless communications system for demand side management*," *IEEE Wireless Communications,vol.19, no. 3, pp. 38–46, Jun. 2012.*
[2] Q.-D. Ho, Y. Gao, G. Rajalingham, and T. Le-Ngoc, *Wireless Communications Networks for the Smart Grid. Springer Publishing Company, Incorporated,2014.*
[3] N. Kilic and V. C. Gungor, "*Analysisof low power wireless links in smart grid environments," Computer Networks*,vol. 57, no. 5, pp. 1192–1203, Apr. 2013.
[4] H. Shi, F. Ning, W. Li, and T. A. Gulliver, "*Cooperative communicationsand mesh networks for the smart grid data backhaul," in 2013 IEEE Pacific Rim Conference on Communications, Computers and Signal Processing (PACRIM). IEEE, Aug. 2013, pp. 313–317.*
[5] M. H. U. Ahmed, M. G. R. Alam, R. Kamal, C. S. Hong, and S. Lee, "*Smart grid cooperative communication with smart relay," Journal of Communications and Networks, vol. 14, no. 6, pp. 640–652, Dec. 2012.*
[6] I. Zahiri, J. Hamedoun, H. Bouzekri, and G. Aniba, "*Cooperative Wireless Transmission for Smart Metering," in 2016 IEEE International Conference on Smart Grid Communications (SmartGridComm).*