Energy Efficient Control Scheme in Wireless Sensor Networks

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Abstract

In this paper, we consider wireless sensor networks with hard energy constraint, where each node is powered by a small battery. Under this hard constraint, reducing energy consumption is the most important design consideration for wireless sensor networks. Energy saving and control is an important issue, involved in the design of most sensor nodes. In this context, we focus on physical layer design where energy constraint problem can be modeled as an optimization of transmission modulation scheme[1]. Specifically, our analyses are based on energy control schemes that are relative to physical layer design on upper bound SEP MPSK in AWGN channels.

I. Introduction

In order to address these needs, optimal strategies to minimize the total energy consumption for upper bound SEP MPSK in AWGN channels are proposed. Several main factors should be taken in consideration while implementing techniques such as overall energy consumption, transmission time, peak - power and delay constraints. The overall design can be modeled as minimizing the energy consumption under several given constraints, by choosing optimal transmission modulation scheme.

The remainder of this paper is organized as follows: Section II describes the analysis of energy control scheme in physical layer design for upper bound SEP MPSK in AWGN channels, Section III discusses the analysis of numerical result on upper bound SEP MPSK in AWGN channels, Section IV summarizes on the analysis and give the conclusions.

II. Analysis of Energy Efficiency Upper Bound SEP MPSK in AWGN Channel

Approximate expression for SEP MPSK in AWGN channel was derived by Craig[2],[3] as equation (1). Where, this approach is accurate at both low and high SNR, furthermore valid for all the SEP MPSK.

$$P_s(E) = \frac{1}{\pi}\int_0^{\frac{(M-1)\pi}{M}} e^{-\left(\frac{E_s}{N_0}\frac{g_{psk}}{\sin^2\theta}\right)} d\theta = \frac{1}{\pi}\int_0^{\frac{(M-1)\pi}{M}} e^{-\left(\frac{\gamma g_{psk}}{\sin^2\theta}\right)} d\theta \qquad (1)$$

where $g_{psk} = \sin^2\frac{\pi}{M}$ and $\gamma = \frac{E_s}{N_o}$

By using equation (1) we derived formula for upper bound SEP MPSK in AWGN channel for modulation optimization under energy constrained. Firstly, we assume the symbol period is Ts and the number of bits per symbol is $b = \log_2 M$ The number of symbols needed for sending L bits is $L_s = \frac{L}{b} = \frac{T_{on}}{T_s}$ where $b = \frac{LT_s}{T_{on}} = \frac{L}{BT_{on}}$, while the bandwidth B is defined as $B = \frac{1}{T_s}$. The Signal to Noise Ratio ɣ is defined as $\gamma = \frac{P_r}{2B\sigma^2 N_f}$ where P_r is the received signal power, σ^2 is the power spectral density of the AWGN and $N_f = \frac{N_{total}}{2\beta\sigma^2}$ is the noise created by the receiver and Ntotal is the total noise power which combines the channel noise and the noise introduced by all receiver circuits.. By approximating the bound as equality. With this assumption, we can obtain the required received signal power as:

$$P_r \approx \frac{2B\sigma^2 N_f}{\sin^2\left(\frac{\pi}{M}\right)} \ln\left(\frac{M-1}{M}.\frac{1}{P_s}\right) \qquad (2)$$

Assuming free space propagation in our model, so the upper bound of the power transmission for SEP MPSK in AWGN channel becomes:

$$P_t \approx \frac{2B\sigma^2 N_f}{\sin^2\left(\frac{\pi}{2^{\frac{L}{BT_{on}}}}\right)} \ln\left(\frac{2^{\frac{L}{BT_{on}}}-1}{2^{\frac{L}{BT_{on}}}}.\frac{1}{P_s}\right).G_d \qquad (3)$$

From equation (2), the total energy consumption per bit in term of Ton for upper bound SEP MPSK in AWGN channel is given by :

$$E_{total} \approx \left\{ (1+\alpha)\frac{2B\sigma^2 N_f}{\sin^2\left(\frac{\pi}{2^{\frac{L}{BT_{on}}}}\right)} \ln\left(\frac{2^{\frac{L}{BT_{on}}}-1}{2^{\frac{L}{BT_{on}}}}\cdot\frac{1}{P_s}\right) G_d.T_{on} + P_c T_{on} + 2P_{syn}T_{tr} \right\} / L \quad (4)$$

The energy consumption optimal problem for upper bound SEP MPSK in AWGN channel is modeled as:

Minimize E_{total}

Subject to $T_{min} \le T_{on} \le T_{max} - T_{tr}$ (5)

Ⅲ. Analysis and Numerical Result

Table.1 MPSK Parameter

N_f =10dB	$T_{tr} = 5\mu s$
$\sigma^2 = 10^{-16} W/Hz$	$T_{max} = 100ms$
$P_e = 10^{-3}$	$P_{max} = 300mW$
$B = 1MHz$	$\alpha = 1.9$
$L = 200Kb$	$P_{IFA} = 3mW$
$P_{syn} = 50mW$	$P_{fil} = 5mW$
$f = 2.4GHz$	$P_{mix} = 30.3mW$
G = 1	$T_s = \frac{1}{B}$

Fig.1 shows the total energy consumption per information bit versus normalized transmission time T_{on}/T, where T = (T_{max} - T_{tr}) for a different *d* by using the upper bound SEP MPSK in AWGN channel. We can see at fig.1, when the transmission distance *d* is small, it is no longer a monotonically – decreasing function over T_{on}/T. We can find an optimal T_{on}/T minimizing E_{total}. For example, when *d* = 0.3m, E_{total} at the optimal Ton 0.16T is about 6.1dB lower than the non-optimized where T_{on}= $T-T_{tr}$ ≈ T. Non - trivial energy saving occurs when distance is very small (e.g *d* = 0.3m). Since transmission energy increase with *d*, there is no energy saving possibility by optimizing T_{on}. From fig.1 at *d* = 4m is at threshold, because the derivative E_{total} relative to T_{on} is approximately zero. For this case, we only need to use the allowable maximum T_{on}/T = 1 to minimize the total energy consumption.

Fig.2 shows the total energy consumption per information bit versus the constellation size of upper bound SEP MPSK in AWGN channel, for *d* = 0.3m and *d* = 10m, other parameters are as the same as Table.1. From here we can predict the relationship between *b* and T_{on} and achieve the same result as fig.2. For small distance d, the transmission energy is monotonically-decreasing function over T_{on}. I.e., it is monotonically-increasing with *b*, while the total energy is not monotonically changing with *b*. It is minimized at b_{opt} ≈ 5. Thus, the minimal total energy consumption is achieved at $b=2$, which is the minimum value.

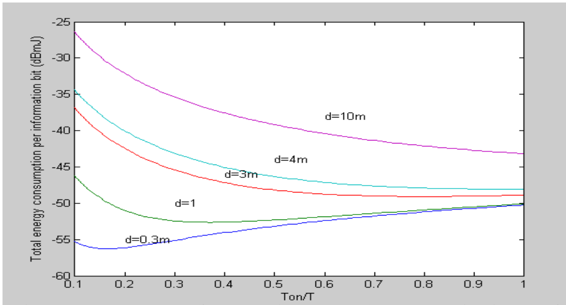

Fig.1. Total Energy Consumption upper bound MPSK in AWGN channel versus Normalized Transmission Time

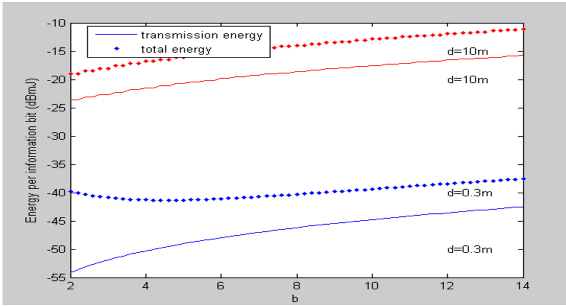

Fig. 2. Total Energy Consumption versus Constellation Size upper bound M-PSK in AWGN Channel

Ⅳ. Conclusion

In this paper, we proposed optimum methods that belong to physical layer focusing on optimal energy analysis. Based on simulation, we showed that for transmitting a given number of bits in a point-to-point communication link, we need to minimize the transmission energy for maximum transmission. To minimize the total energy consumption, the transmission time needs to be optimized as well. From the result, we observed that optimization at upper bound SEP MPSK in AWGN channel needed to minimize the required total energy consumption in order to meet a given SEP requirement. This also can be done by optimizing the transmission time.

The transmission time is bounded above by the delay requirement and below the peak – power constraint. The transmission energy is analyzed via probability of error bound approximations and the circuit energy consumption is approximated as a linear function of the transmission time. With this optimization, we also find the optimal constellation size for the upper bound SEP MPSK in AWGN channels.

Ⅴ. References

[1] S. Cui, A. J. Goldsmith, and A. Bahai, "Energy -constrained Modulation optimization","http://wsl.stanford.edu/ Publications/Shuguang /siso_submitted.pdf "

[2] M.K Simon and M.S. Alouini,"Digital Communication Over Fading Channels, a unified approach to performance Analysis", Willey 1999.

[3] K. Lever, "New derivation of Craig's formula for the Gaussian probability function,"Electron. Lett., vol. 34, September 1998.