International Journal of Scientific & Engineering Research Volume 8, Issue 4, April 2017
I099266

Partial OFDM Demodulation for Frequency Synchronization of WSN

Anjali Gupta
Department of Electronics & Communication
Sagar Institute of Research & Technology
Indore (M.P.), India
anjali.gupta1310@gmail.com

Shivangini Maurya
Department of Electronics & Communication
Sagar Institute of Research & Technology
Indore (M.P.), India
shivangini.saxena@trubainstitute.ac.in

Abstract — Wireless sensor network is the emerging technology and is adopted quickly due to its variety of environment and flexibility towards users. However, these networks consist of tiny size nodes, economical designing of devices or nodes that possess several prevention as limited bandwidth, limited processing power, short battery life and less storage capacity. Synchronization of a Wireless Sensor Network is a crucial task and is based on a precise syntonization of all clocks within the network. The synchronization precision is usually closely connected to the positioning accuracy in networks for the purpose of localization. This paper introduces a concept, how the clocks of low-complexity stationary receivers can be adjusted to the same frequency with the help of a television broadcast signal. Only parts of the signal information are used to achieve a manageable data rate for the embedded low-power processor. With a new algorithm the performance of the frequency estimation can be kept high compared to the use of the total signal energy, while the processing load can be reduced dramatically.

Keywords- OFDM, Estimation, Bandwidth, digital video broadcasting, clocks, receiver, oscillator, partial OFDM demodulation, synchronization.

1. **INTRODUCTION**

A wireless sensor network comprises of large number of low cost low power multi functional sensor nodes which are highly distributed either inside the system or very close to it. Sensor nodes cooperate in order to merge individual sensor readings into a high-level sensing result, such as integrating a time series of position measurements into a velocity estimate. The physical time of sensor readings is a key element in this process called data fusion. Hence, time synchronization is a crucial component of WSN. In addition, many thousands of sensors may have to be deployed for a given task an individual sensor's small effective range relative to a large area of interest makes this a requirement, and its small form factor and low cost makes this possible. Therefore, *scalability* is another critical factor in the design of the system.

In WSN, the sensor nodes have a limited transmission range, and their processing and storage capabilities as well as their energy resources are also limited. Routing protocols for wireless sensor networks are responsible for maintaining the routes in the network and have to ensure reliable multi-hop communication under these conditions. In this paper, we give a survey of routing protocols for Wireless Sensor Network and compare their strengths and limitations.

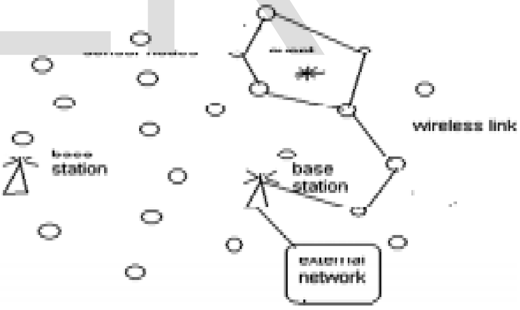

Figure.1. Wireless sensor network

Orthogonal frequency division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters. OFDM requires very accurate frequency synchronization between the receiver and the transmitter; with frequency deviation the sub-carriers will no longer be orthogonal, causing inter-carrier interference (ICI) (i.e., cross-talk between the sub-carriers). Frequency offsets are typically caused by mismatched transmitter and receiver oscillators, or by Doppler shift due to movement. While Doppler shift alone may be compensated for by the receiver, the situation is worsened when combined with multipath, as reflections will appear at various frequency offsets, which is much harder to correct. This effect typically worsens as speed increases, and is an important factor limiting the use of OFDM in high-speed vehicles. In order to mitigate ICI in such scenarios, one can shape each sub-carrier in order to minimize the interference resulting in a non-orthogonal subcarriers overlapping.[4] For example, a low-complexity scheme referred to as WCP-OFDM (Weighted Cyclic Prefix Orthogonal Frequency-Division Multiplexing) consists of using short filters at the transmitter output in order to perform a potentially non-rectangular pulse shaping and a near perfect reconstruction using a single-tap per subcarrier equalization. Other ICI suppression techniques usually increase drastically the receiver complexity.

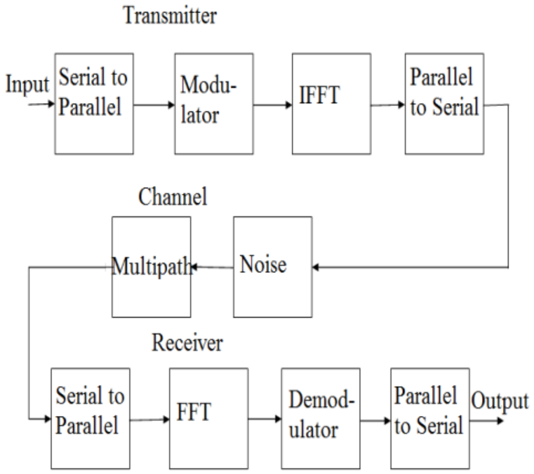

Figure.2. OFDM system model

OFDM simulation model consists of transmitter, channel and receiver. At the transmitter end data is generated by random data generator. Then these data are converted from serial to parallel. Modulator is used to modulate the data. Then before applying parallel to serial IFFT (Inverse Fast Fourier Transformation) operation is used. Then at the channel noise and multipath fading are added to the data. At the receiver end firstly serial to parallel conversion of data is done the FFT operation is used before demodulate the data. Before output again data is converted in the form of serial.

2. OFDM PARAMETERS AND CHARACTERISTICS

The number of carriers in an OFDM system is not only limited by the available spectral bandwidth, but also by the IFFT size (the relationship is described by number of carriers$\leq \frac{ifft_size}{2} - 2$ which is determined by the complexity of the system [10]. The more complex (also more costly) the OFDM system is, the higher IFFT size it has; thus a higher number of carriers can be used, and higher data transmission rate achieved. The choice of *M*-PSK modulation varies the data rate and Bit Error Rate (BER). The higher order of PSK leads to larger symbol size, thus less number of symbols needed to be transmitted, and higher data rate is achieved. But this results in a higher BER since the range of 0-360 degrees of phases will be divided into more sub-regions, and the smaller size of sub-regions is required, thereby received phases have higher chances to be decoded incorrectly. OFDM signals have high peak-to-average ratio, therefore it has a relatively high tolerance of peak power clipping due to transmission limitations.

ORTHOGONALITY

The key to OFDM is maintaining orthogonality of the carriers. If the integral of the product of two signals is zero over a time period, then these two signals are said to be orthogonal to each other. Two sinusoids with frequencies that are integer multiples of a common frequency can satisfy this criterion. Therefore, orthogonality is defined by:

$$\int_0^T \cos(2\pi n f_o t)\cos(2\pi m f_o t)dt = 0 \quad (n \neq m)$$

where n and m are two unequal integers, fo is the fundamental frequency, T is the period over which the integration is taken. For OFDM, T is one symbol period and fo set to $1/T$ for optimal effectiveness [11 and 12].

3. SYSTEM MODEL

A. Signal Model

The transmitted OFDM signal in pass band can be compactly written as

$$s(t) = \text{Re}\left[\sum_{l=1}^{K} d_l e^{j2\pi f_l t}\right], \quad t \in [-T_g, T] \qquad (1)$$

where dk are the data symbols modulated onto the K subcarriers, fk = f0 + (k - 1)∆f is the frequency of the kth subcarrier, f0 is the frequency of the first subcarrier, Tg and T are the cyclic prefix and the OFDM symbol duration respectively and ∆f = 1/T . The cyclic extension is assumed to be long enough to capture the effects of channel multipath and Doppler spreading. Assuming constant channel gains hp, p = 1, 2, · · · , P and linearly varying path delays τp(t) = τp - at over one OFDM symbol duration, the complex valued received signal can be expressed as

$$r(t) = \sum_{l=1}^{K} d_l H_l e^{j2\pi f_l t(1+a)} + n(t), \quad t \in [0, T] \qquad (2)$$

where $H_k = \sum_{p=1}^{P} h_p e^{-j2\pi f_k \tau_p}$ τp is the channel frequency response on the kth carrier and n(t) is additive white Gaussian noise (AWGN). The Doppler distortion due to time scaling is modeled with the parameter a = v/c, where v is the relative velocity between the transceivers and c =1500m/sec is the speed of sound in water. Typical values of the order of 10-3 for objects moving at a few meters per second (e.g., at v = 1.5m/sec ⇒ a = 10-3). The signal is first resampled at the receiver to compensate for the time scaling due to Doppler. However, inaccuracies in Doppler estimation result in residual time scaling. In this paper, the Doppler distortion parameter a is the residual signal scaling factor after resampling at the receiver and is typically on the order of 10^{-4}.

B. Partial FFT Demodulation

Assuming the generic channel model the signal at the receiver can be expressed

$$\begin{aligned} r(t) &= Re\left\{\sum_{p=1}^{P} h_p(t) s(t - \tau_p(t))\right\} + n(t) \\ &= Re\left\{\sum_{p=1}^{P}\sum_{l=1}^{K} h_p(t) d_l e^{j2\pi f_l (t-\tau_p(t))}\right\} + n(t). \qquad (3) \end{aligned}$$

We assume that the timing synchronization is precise. After removal of the cyclic prefix, the OFDM block interval of duration *T* is divided into *M* non-overlapping intervals, and each is assigned to one partial FFT demodulator. The output of the *mth* partial demodulator for the *kth* OFDM subcarrier is given by

$$\begin{aligned} y_k(m) &= \frac{1}{T}\int_{\frac{(m-1)T}{M}}^{\frac{mT}{M}} r(t) e^{-j2\pi f_k t} dt \\ &= \sum_p \sum_l d_l \int_{\frac{(m-1)T}{M}}^{\frac{mT}{M}} h_p(t) e^{-j2\pi f_l \tau_p(t)} e^{j2\pi (f_l - f_k) t} dt \\ &\quad + n_k(m), \; m = 1, 2, \cdots, M. \qquad (4) \end{aligned}$$

The noise terms *nk* (*m*) are independent for a fixed subcarrier *k* and varying *m*, but are correlated for a fixed *m* and varying *k*. If the path gains and the delays are slowly varying over the interval *T/M*, The received signal can then be approximated as

$$\begin{aligned} y_k(m) &\approx \sum_{p=1}^{P}\sum_{l=1}^{K} d_l h_p(m) e^{-j2\pi f_l \tau_p(m)} I_{l-k}(m) + n_k(m) \\ &= \sum_{l=1}^{K} d_l H_l(m) I_{l-k}(m) + n_k(m), \qquad (5) \end{aligned}$$

Where *hp*(*m*) and *τp*(*m*) are the relevant mid-point values of the path gains and delays. The effective channel gain as seen by the *kth* subcarrier in the *m*-th demodulation interval [(*m*-1)*T/M*, *mT/M*] can then be expressed as

$$H_k(m) = \sum_{p=1}^{P} h_p(m) e^{-j2\pi f_k \tau_p(m)}$$

The function *Ii*(*m*) describes the effect of partial integration and is given by

$$I_i(m) = \int_{\frac{(m-1)T}{M}}^{\frac{mT}{M}} e^{j2\pi i \Delta f t} dt, i = -(K-1), \ldots (K-1).$$

We note that $\sum_m I_i(m) = \delta_i$

For the special case of a channel with linearly varying path delays, the time-varying frequency response can be expressed as

$$H_k(m) = e^{j2\pi f_k a \frac{(2m-1)T}{2M}} \left[\sum_p h_p(m) e^{-j2\pi f_k \tau_p}\right], \qquad (6)$$

where *a* is the Doppler scaling factor.

4. **CONCLUSION**

An extensive demonstration of OFDM system has been presented in this paper. The proposed system is studied with concern to partial FFT demodulation for frequency synchronization. In this paper parameter and characteristic of OFDM system with orthogonality principle is discussed. The mathematical expressions of partial fft demodulation and system model of the OFDM system is studied. This paper proposes a theory on OFDM system with respect to low complexity stationary receivers can be matched to same frequency. Numerical simulations and the significant performance improvements will be further obtained using the proposed techniques.

REFERENCES

[1] Clint Smith and Daniel Collins, “3G Wireless Networks”, 2nd edition, 2008.

[2] M. Mirahmadi, Member, IEEE, A.Al-Dweik, Senior Member, IEEE, and A.Shami, Senior Member, IEEE, “BER Reduction of OFDM Based Broadband Communication Systems over Multipath Channels with Impulsive Noise”, IEEE Transactions on Communications, vol.61, No.11, November 2013.

[3] Bernard Skalar and Pabritra Kumar Ray, “Digital Communication: Fundamentals and Applications”, Pearson, Edison 2, Jan.2009.

[4] Proakis John G., Salehi M., -Communication System Engineering, Prentice Hall of India, Edition 2, 2005.

[5] Orthogonal Frequency Division Multiplexing, U.S. Patent No. 3, 488, 4555, filed November14, 1996, issued Jan.6, 1970.

[6] Vendee-Ramjee, “OFDM for Wireless Multimedia Communications”.

[7] Y. Wu and W. Y. Zou, “Orthogonal frequency division multiplexing: A multi-carrier modulation scheme”, IEEE Transaction. Consumer Electronics, vol.41, no.3, pp. 392 399, Aug. 1995.

[8] S. Yerramalli, M. Stojanovic, and U. Mitra. Partial FFT demodulation: A detection method for Doppler distorted OFDM systems. In International Workshop on Sig. Proc. Advances in Wireless Comm., (SPAWC) 2010.

[9] I Kim, Y Han, H-K Chung, An efficient synchronization signal structure for OFDM-based cellular systems. IEEE Trans. Wireless Communication **9**(1), pp. 99–105 (2010).

[10] B Sheng, J Zheng, X You, L Chen, A novel timing synchronization method for OFDM systems. IEEE Commun. Lett. **14**(12), pp. 1110–1112 (2010).

[11] Q. Huang, M. Ghogho, J. Wei, and P. Ciblat, “Practical timing and frequency synchronization for OFDM-based cooperative systems”, *IEEE Transactions on Signal Processing*, vol. 58, no. 7, pp. 3706–3716, Jul. 2010.

[12] Y. Li, X. Sha, and K. Wang, “Hybrid carrier communication with partial FFT demodulation over underwater acoustic channels,” *IEEE Commun. Lett.*, vol. 17, no. 12, pp. 2260–2263, Dec. 2013.

[13] Y. Li, X. Sha, F.-C. Zheng, and K. Wang, “Low complexity equalization of HCM systems with DPFFT demodulation over doubly selective channels”, *IEEE Signal Process. Lett.* vol. 21, no. 7, pp. 862–865, Jul. 2014.