Study of Using Wavelet Transform In Wireless Communication

Prashant Kumar, Assistant Professor,

Department of Electrical and Communication Engineering, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India

Email Id- tmu.iqac@gmail.com

ABSTRACT: Wavelets have been widely used in digital wireless communication systems, including data compression, source and channel coding, signal denoising, channel modeling, and transceiver design. Wavelets' primary advantage in these applications is its flexibility and ability to properly describe signals. Recent trends and advances in the usage of wavelets in wireless communications are discussed in this article. Wavelets are used in wireless channel modeling, interference reduction, denoising, OFDM modulation, multiple access, Ultra Wideband communications, cognitive radio, and wireless networks, among other applications. The convergence of information and communication technologies, as well as the potential of ubiquitous connectivity, has made creating systems and architectures capable of processing huge quantities of data under severe resource limitations like as power and bandwidth difficult. Wavelets are particularly suited to tackle this problem. Wavelet technology is a good contender for future wireless communication because of its versatility and adaptability.

KEYWORDS: CDMA, Cognitive Radio, OFDM, Wavelets, Wireless Communications.

1. INTRODUCTION

The Wavelet transform is a method of breaking a signal into a collection of basis waveforms known as wavelets, which may then be analyzed by looking at the coefficients (or weights) of the wavelets. This technique has a wide range of applications and is becoming more popular among technicians, engineers, and mathematicians. The transform's power is derived in most applications from the fact that the transform's basis functions are localized in time (or space) and frequency, and have various resolutions in these domains. The transform's strength comes from the fact that different resolutions frequently correlate to the inherent behavior of the process being studied. Wavelets and wavelet transforms are natural choices in fields like image synthesis, data compression, computer graphics and animation, human vision, radar, optics, astronomy, acoustics, seismology, nuclear engineering, biomedical engineering, magnetic resonance imaging, music, fractals, turbulence, and pure mathematics because of these properties.

Wavelet transform has recently been suggested as a potential analysis method for advanced digital wireless communication systems, with benefits such as transform flexibility, less susceptibility to channel distortion and interference, and improved spectrum use. Wavelets have found use in channel modeling, transceiver design, data representation, data compression, source and channel coding, interference mitigation, signal de-noising, and energy efficient networking, among other areas of wireless communication [1] system design. In this article, we try to compile the most recent advances and discoveries in the area of wireless communication using wavelets and its tributaries, such as wavelet packets. The applications of transmission technology are given special attention. It's worth noting that this isn't a complete analysis of all the available research; rather, it's an effort to assess the possibilities and potentials of wavelets in the design and development of wireless communications systems.

The wavelet transform is a method of transforming data. The term wavelet comes from a French scholar named Jean Morlet [2], who coined the term ondelette, which means "little wave". Later, it was trans- lated into English by changing "onde" to "wave," giving rise to the term wavelets. Wavelets are tiny waveforms having a specified oscillatory structure that is non-zero over a finite length of time (or space) and have other mathematical characteristics, as their name implies. The wavelet transform is a multi-resolution analysis method that decomposes an input signal into various frequency components, which are subsequently examined with resolutions suited to their scales. The Fourier transform similarly decomposes signals into basic waveforms, but sines and cosines are the basis functions [3].

As a result, the Fourier transform is not an effective analytical tool when looking at local characteristics of the input signal, such as edges or transients. Wavelet transformations, on the other hand, which utilize unevenly shaped wavelets, are better at representing abrupt changes and local characteristics. At high frequencies, the wavelet transform provides excellent time resolution but poor frequency resolution, whereas at low frequencies, it provides good frequency resolution but poor time resolution. When the signal contains high frequency components for short periods and low frequency components for extended durations, this method makes sense. Fortunately, this is the kind of signal that is encountered in most engineering applications. The wavelet packet transform is similar to the wavelet transform as shown in figure 1, but it decomposes even the high frequency bands that the wavelet transform leaves intact. The wavelet packet decomposition method is shown in Figure 1. S stands for signal, whereas A and D stand for approximations (high frequency terms) and decompositions, respectively (low frequency terms) [4].
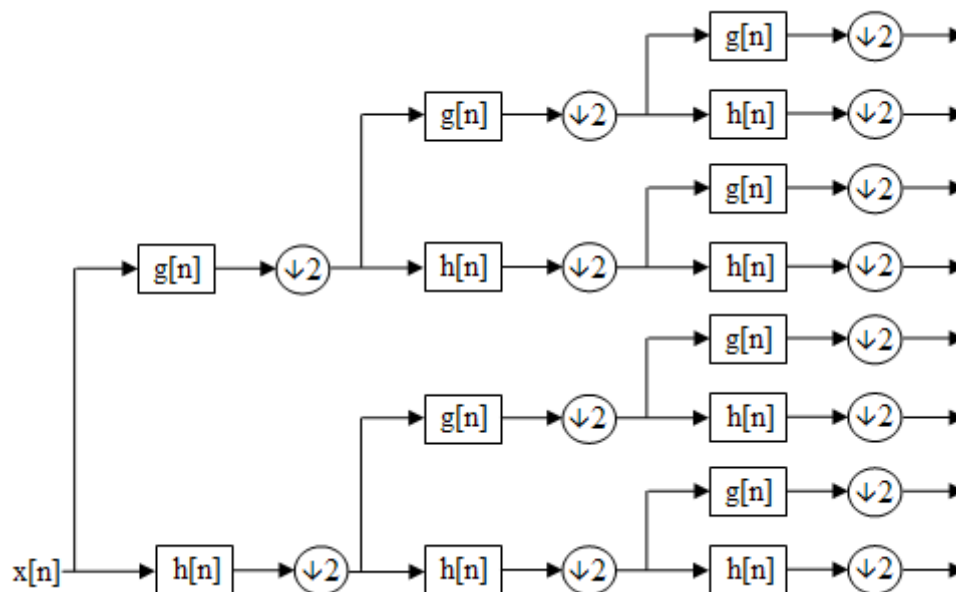

Figure 1: Demonstration of wavelet packet transform.

Subband coding [5] is a hierarchical coding method in which the signal to be coded is divided into high and low frequency components sequentially. The wavelet transform is a kind of subband coding that involves passing the signal to be examined through a sieve of filter banks. The wavelet and scaling function transform coefficients are then computed from the outputs of the various filter stages.

2. DISCUSSION

The filter bank is made up of high pass and low pass filters [6] that repeatedly divide the spectrum into two equal portions. The high-pass portions contain the tiniest details and should not be further processed. The low-pass section, however, still retains some information, thus it is divided again. This dyadic procedure is performed until the desired resolution is achieved. The quantity of data or computing power available usually limits the number of subbands. Wavelets and wavelet packets provide a number of benefits in wireless communication systems. We'll go through a couple of the advantages of wavelets here:

2.1. Semi-arbitrary signal space div ision and multirate systems:

Subcarriers with various bandwidths and symbol lengths may be created using the wavelet transform. Because each subcarrier has the same time-frequency plane area, increasing bandwidth (or decreasing bandwidth) results in a reduction (or rise) in subcarrier symbol length. The wavelets' properties may be used to build a multirate system. Such a capability is advantageous from a communication standpoint for systems that must handle various data streams with varying transport delay requirements [7].

2.2. Time-frequency tiling flexibility

Another benefit of wavelets is their ability to organize time-frequency tiling in such a way that channel disruptions are minimized. The impact of noise and interference on the signal may be reduced by flexibly aligning the time-frequency tiling. Rather of waiting until the receiver to cope with known channel disruptions, wavelet-based systems may overcome them at the transmitter. As a result, they may improve wireless networks' quality of service (QoS).

2.3. Diversity of signal or waveform

Wavelets provide the physical diversities presently used, notably space, frequency, and time-diversity, an additional dimension – "Waveform diversity." Signal diversity, similar to spread spectrum systems, may be used in a cellular communication system where nearby cells communicate with one other.

In order to reduce inter-cell interference, various wavelets may be assigned. Another example is the Ultra Wideband (UWB) communication system, which allows users to share a very wide band with little interference by cleverly sending pulse wave patterns [8].

2.4. Sensitivity to channel effects

The collection of waveforms used by the carriers determines the modulation scheme's performance. As a result, the wavelet technique has the potential to reduce the system's susceptibility to detrimental channel effects such as Inter-symbol interference (ISI) and Inter-carrier interference (ICI).

2.5. Flexibility with sub-carriers

The iterative character of the wavelet transform is closely linked to wavelet derivation. A customizable transform size and therefore a configurable number of carriers are possible with the wavelet transform. This capability may be used, for example, to convert a transceiver to a certain communication protocol; the transform size could be chosen based on channel impulse response characteristics, computational complexity, or connection quality.

2.6. Power efficiency

Data compression has traditionally relied on wavelet-based techniques. This is especially important in the context of mobile wireless devices, which are often energy-strapped. By compressing the data, a smaller amount of data is sent, lowering the amount of communication power required for transmission [9].

2.7. Denoising and mitigation of interference

Interference in a communication channel may be caused by a variety of factors, including accidental, deliberate (jamming), symbol overlap owing to temporal spreading (Intersymbol interference or ISI), and neighboring channel interference (Interchannel interference or ICI). Wavelets, by virtue of their intrinsic flexibility, provide the keys to effectively distinguish the signal from the noise (denoising) while reducing interference and noise impacts. This section provides an overview of the work that has been done in this area. The successful use of a wavelet-based denoising method [10] to enhance power delay profile estimations in indoor wideband settings shows how to estimate the time difference of arrival (TDOA) for GSM signals in noisy channels using a wavelet-based de-noising technique. Composite wavelet shrinkage is used to denoise signals with low SNR. Finally, wavelet-based digital signal processing algorithms are suggested to fight high-power non-stationary noise in infrared wireless networks, where various wavelet techniques are assessed for denoising and their efficacy is validated via simulations.

2.8. Modulation and multiplexing wavelets

The synthesis and analysis parts of digital communication systems may be regarded as generic transmultiplexer systems [11]. The filter set employed in both the synthesis and analysis portions is a key component that contributes to the system's characterisation. The kind of communication system will be determined by the time-frequency characteristics of these filters, i.e. time spread and frequency spread (TDMA, FDMA, CDMA, OFDM, MC-CDMA, MC-DS- CDMA). The wavelet filters that characterize these systems, unlike current implementations, are generated from wavelet bases (i.e. non-Fourier basis). The increased need for radio bandwidth has been driving recent advances in wireless communications. The development of new signal transmission methods that allow for substantial improvements in wireless capacity without increasing bandwidth has been a major focus of this effort. With this rising need, one may be tempted to speculate on the potential benefits of more sophisticated transforms, such as the wavelet transform, over more traditional setups. Indeed, there have been concentrated efforts in this area, and we will give an overview of the different initiatives related to the use of wavelets in modulation and demodulation schemes in this section.

2.9. Wavelets for Multicarrier Modulation

MCM (Multi-Carrier Modulation) is a data transmission method in which a data stream is split into many parallel bit streams, each with a lower bit rate, and the substreams are used to modulate multiple carriers. OFDM (Orthogonal Frequency Division Multiplexing) is an MCM system that uses orthogonal sine/cosine waves as subcarriers. The rectangular window employed in this design has a significant disadvantage in that it generates high side lobes. Furthermore, in the frequency domain, the pulse shaping function utilized to modulate each sub-carrier stretches to infinity. This results in a lot of interference and poor performance. Wavelet-based basis functions have emerged as attractive candidates for MCM in wireless channels, promising more flexibility and enhanced performance against channel effects. Fourier-based systems, on the other hand, are said to outperform their wavelet-based equivalents for wired channels.

3. CONCLUSION

Wavelets have a wide range of applications in wireless communications, from source and channel coding to transceiver design, as well as from the wireless physical channel to the network and higher layers. The ability and flexibility of wavelets to describe signals with adjustable time-frequency resolution is a key feature for many applications. The goal of this

article was to give an overview of wavelet applications in wireless communications, illustrating the wide range of potentials and possibilities that wavelets may bring. With the confluence of information, multimedia, entertainment, and wireless communications, the goal of ubiquitous communication is becoming a reality. To make this a reality, technology and systems capable of processing huge quantities of data under severe resource limitations, such as power and bandwidth, must be developed. Wavelets are particularly suited to tackle this problem. They have the distinct benefit of being generic schemes with the ability to be extensively modified to meet the different needs and limitations of modern mobile communications systems. For smart and resource-aware wireless networks, wavelet technology is the best option. With existing systems and technologies, the flexibility offered by wavelet technology cannot be completely utilized. As a result, wavelet technology is expected to be a strong contender for next-generation wireless networks.

REFERENCES:

[1]   A. A., "Discrete Wavelet Transform Based Wireless Digital Communication Systems," in *Discrete Wavelet Transforms - Theory and Applications*, 2011. doi: 10.5772/16050.

[2]   J. Morlet, G. Arens, E. Fourgeau, and D. Giard, "Wave propagation and sampling theory - Part I. Complex signal and scattering in multilayered media.," *Geophysics*, 1982, doi: 10.1190/1.1441328.

[3]   R. A. Fayadh, F. Malek, H. A. Fadhil, S. K. Salih, and F. S. Abdullah, "Design of a UWB wireless indoor rake receiver using continuous and discrete wavelet transform approaches," *J. Theor. Appl. Inf. Technol.*, 2014.

[4]   A. N. Akansu, W. A. Serdijn, and I. W. Selesnick, "Emerging applications of wavelets: A review," *Phys. Commun.*, 2010, doi: 10.1016/j.phycom.2009.07.001.

[5]   M. Vetterli and J. Kovačević, "Wavelets and Subband Coding," *Book*, 1995.

[6]   C. Author, N. Khan, M. Alam, A. Masud, and A. Amin, "Importance of High Order High Pass and Low Pass Filters," *World Appl. Sci. J.*, 2016.

[7]   M. P. Prabakaran, A. Sivasubramanian, and K. Chitra, "Wavelet packet transform based de-noising receiver for indoor optical wireless system," *IEICE Electron. Express*, 2014, doi: 10.1587/elex.11.20140346.

[8]   M. Tabaa, "A Novel Transceiver Architecture Based on Wavelet Packet Modulation for UWB-IR WSN Applications," *Wirel. Sens. Netw.*, 2016, doi: 10.4236/wsn.2016.89016.

[9]   S. Rein and M. Reisslein, "Low-memory wavelet transforms for wireless sensor networks: A tutorial," *IEEE Commun. Surv. Tutorials*, 2011, doi: 10.1109/SURV.2011.100110.00059.

[10] X. H. Jiang, C. X. Xie, and Y. B. Zou, "A denoising method of monitoring information under strong noise," *Huanan Ligong Daxue Xuebao/Journal South China Univ. Technol. (Natural Sci.*, 2011, doi: 10.3969/j.issn.1000-565X.2011.04.012.

[11] H. Zhou and L. Xie, "Optimal design of noisy transmultiplexer systems," *EURASIP J. Appl. Signal Processing*, 2006, doi: 10.1155/ASP/2006/64645.