Analysis of OFDM for Clock Synchronization on Wireless Sensor Network

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ABSTRACT

In this research, the Orthogonal frequency division multiplexing (OFDM) method is proposed to remove the clock offset and clock skew among the sensor nodes. The clock synchronization method influences security and redundancy rate by selecting the most influencing cluster head. The proposed OFDM enables the nodes to reach a network synchronization time by calculating the least common multiple of their Clock Time Period (CTP). The network is organized into clusters and every node reaches the network synchronization time using its own CTP. Simulation results show that, the OFDM algorithm is more efficient compared to the Average Time Synchronization with Pair wise messages (ATSP) in terms of accuracy, communication overhead, and computation overhead. Multiple Input Multiple Output (MIMO) in combination with Orthogonal Frequency Division Multiplexing (OFDM) can provide spectrally efficient and ISI free communication. MIMO technology transmits signal through multiple antennas there by multiplying capacity and OFDM provides transmission at high speeds. MIMO - OFDM is a powerful combination technique for current and future broadband wireless communications. Channel estimation is of great importance in order to recover the signal at the receiver side. Therefore accurate channel state information is essential for proper detection and decoding in MIMO-OFDM wireless systems.

***Keywords:* Bandwidth, CTP, Massive MIMO, OFDM, Skew rate**

I. INTRODUCTION

With the advancement of technology, transmission and distribution of digital multimedia data (image, audio, video, etc.) become vulnerable to unauthorized duplication. Therefore, now-a-days watermarking techniques that can verify the authenticity of the digital data are important to protect the intellectual properties or copyrights in digital images . Some essential features of image watermarking are invisibility, robustness and security. The technology of digital watermarking has recently attracted to improve the robustness against several types of attacks. Many watermarking schemes have been presented using frequency domain and singular value decomposition (SVD) .

The capability of WSN to track, monitor, detect an event, and aggregate data, makes it very suitable for realizing various functionalities in a smart city. To name a few applications of the WSN in the smart city, WSN is used for monitoring the structural health of the monuments, bridges and skyscrapers, for smart management of solid waste , for detecting air pollution levels, for smart vehicle login in the smart city, traffic control and

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smart parking, and for smart metering to reduce power consumption in every household of the smart city . The basic component of the WSN is the communication node, which collects the desired data from its environment periodically or during an event. It processes the data and communicates with other nodes in the network, for executing a process. The data aggregation from the communication nodes can be (a) The exact moment of time, the event had occurred in the network,

(b) The duration between two distinct events and

(c) The sequence of the events that occurred in the network.

The various protocols for clock synchronization are some of the protocols have an external reference clock to which all the nodes synchronize. In these protocols, either the hardware clock or virtual clock is modified to synchronize with the network synchronization time. Each time the clock value is updated at a node, there is an inherent error, which is passed on to other nodes as this propagates, resulting in greater accumulative error by the time the network synchronization is reached. Some protocols modify the clock recursively to achieve synchronization

1.1 MIMO-OFDM Systems

MIMO-OFDM is the foundation for most advanced wireless local area network (wireless LAN) and mobile broadband network standards because it achieves the greatest spectral efficiency and, therefore, delivers the highest capacity and data throughput. Different data streams could be transmitted at the same time on the same frequency by taking advantage of the fact that signals transmitted through space bounce off objects (such as the ground) and take multiple paths to the receiver. That is, by using multiple antennas and pre-coding the data, different data streams could be sent over different paths. The processing required by MIMO at higher speeds would be most manageable using OFDM modulation, because OFDM converts a high-speed data channel into a number of parallel lower-speed channels.

1.2Advantages of MIMO-OFDM

OFDM is that Fast Fourier Transforms (FFTs) may be used to simplify implementation. Fourier transforms convert signals back and forth between the time domain and frequency domain. Consequently, Fourier transforms can exploit the fact that any complex waveform may be decomposed into a series of simple sinusoids. In signal processing applications, discrete Fourier transforms (DFTs) are used to operate on real-time signal samples..

FFTs also enable OFDM to make efficient use of bandwidth. The sub-channels must be spaced apart in frequency just enough to ensure that their time-domain waveforms are orthogonal to each other. In practice, this means that the sub-channels are allowed to partially overlap in frequency.

1.3Applications of MIMO-OFDM

- Wireless Network
- Use more frequency spectrum
- Wi-Fi , Wi-MAX , W-MAN
- Digital –TV
- Power-line control

- DAB (Digital Audio Broadcasting)
- DVB-T (Digital Video Broadcasting)
- DMT (Discrete Multi-Tone System)

II. SYSTEM METHODOLOGY

2.1Orthogonal Frequency Division Multiplexing

OFDM, orthogonal frequency division multiplexing has gained a significant presence in the wireless market place. The combination of high data capacity, high spectral efficiency, and its resilience to interference as a result of multi-path effects means that it is ideal for the high data applications that have become a major factor in today's communications scene.

OFDM is a form of multicarrier modulation. An OFDM signal consists of a number of closely spaced modulated carriers. When modulation of any form – voice, data, etc. is applied to a carrier, then sidebands spread out either side. It is necessary for a receiver to be able to receive the whole signal to be able to successfully demodulate the data. As a result when signals are transmitted close to one another they must be spaced so that the receiver can separate them using a filter and there must be a guard band between them. This is not the case with OFDM. Although the sidebands from each carrier overlap, they can still be received without the interference that might be expected because they are orthogonal to each another. This is achieved by having the carrier spacing equal to the reciprocal of the symbol period.

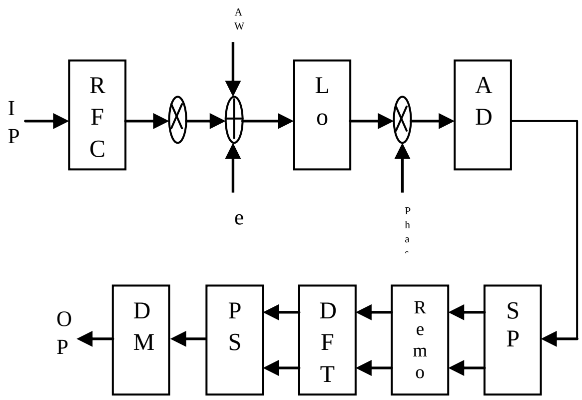

Fig.1: Block Diagram of OFDM system

Data on OFDM

The data to be transmitted on an OFDM signal is spread across the carriers of the signal, each carrier taking part of the payload. This reduces the data rate taken by each carrier. The lower data rate has the advantage that interference from reflections is much less critical. This is achieved by adding a guard band time or guard interval into the system. This ensures that the data is only sampled 2when the signal is stable and no new delayed signals arrive that w3ould alter the timing and phase of the signal.

The distribution of the data across a large number of carriers in the OFDM signal has some further advantages. Nulls caused by multi-path effects or interference on a given frequency only affect a small number of the carriers, the remaining ones being received correctly. By using error-coding techniques, which does mean

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adding further data to the transmitted signal, it enables many or all of the corrupted data to be reconstructed within the receiver. This can be done because the error correction code is transmitted in a different part of the signal.

2.2 OFDM Advantages & Disadvantages

OFDM Advantages

OFDM has been used in many high data rate wireless systems because of the many advantages it provides.

- Immunity to selective fading : One of the main advantages of OFDM is that is more resistant to frequency selective fading than single carrier systems because it divides the overall channel into multiple narrowband signals that are affected individually as flat fading sub-channels.
- Resilience to interference :Interference appearing on a channel may be bandwidth limited and in this way will not affect all the sub-channels. This means that not all the data is lost.
- Spectrum efficiency :Using close-spaced overlapping sub-carriers, a significant OFDM advantage is that it makes efficient use of the available spectrum..

OFDM Disadvantages

While OFDM has been widely used, there are still a few disadvantages to its use which need to be addressed when considering its use.

- High peak to average power ratio : An OFDM signal has a noise like amplitude variation and has a relatively high large dynamic range, or peak to average power ratio. This impacts the RF amplifier efficiency as the amplifiers need to be linear and accommodate the large amplitude variations and these factors mean the amplifier cannot operate with a high efficiency level.
- Sensitive to carrier offset and drift : Another disadvantage of OFDM is that is sensitive to carrier frequency offset and drift. Single carrier systems are less sensitive.

2.3Multiple-Input Multiple-Output

MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver to enable a variety of signal paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used.

One of the core ideas behind MIMO wireless systems space-time signal processing in which time (the natural dimension of digital communication data) is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas, i.e. the use of multiple antennas located at different points.

It is found between a transmitter and a receiver, the signal can take many paths. Additionally by moving the antennas even a small distance the paths used will change.

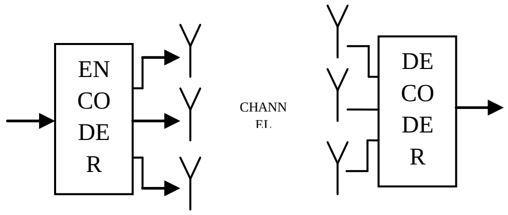


Fig. 2: Block Diagram of MIMO System

MIMO Formats

The two main formats for MIMO are given below:

- Spatial diversity : Spatial diversity used in this narrower sense often refers to transmit and receive diversity. These two methodologies are used to provide improvements in the signal to noise ratio and they are characterized by improving the reliability of the system with respect to the various forms of fading.
- Spatial multiplexing : This form of MIMO is used to provide additional data capacity by utilising the different paths to carry additional traffic, i.e. increasing the data throughput capability.

As a result of the use of multiple antennas, MIMO wireless technology is able to considerably increase the capacity of a given channel while still obeying Shannon's law. By increasing the number of receive and transmit antennas it is possible to linearly increase the throughput of the channel with every part of antennas added to the system

2.4Discrete Wavelet Transform

In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures both frequency and location information (location in time).

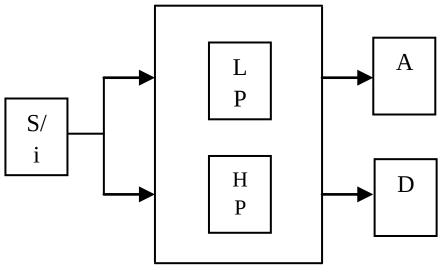


Fig. 3: Block Diagram of DWT System.

2.5 STEGANOGRAPHY

Unlike encryption, where it's obvious that a message is being hidden, steganography hides data in plain view, inside a file such as a picture. As far as images are concerned, to anyone who isn't aware that it contains hidden data, it looks like just a normal, innocent picture.

Steganography is useful in situations where sending encrypted messages might raise suspicion, such as in countries where free speech is suppressed. It's also frequently used as a digital watermark to find when images or audio files are stolen.

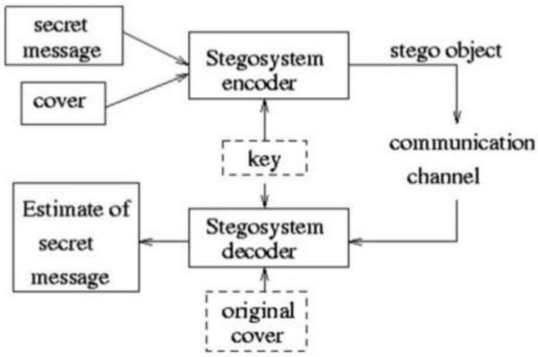


Fig. 4: Block Diagram of Steganography System

III. SYSTEM IMPLEMENTATION

System implementation is made up of many activities. The six major activities used in project development are as follows.

Coding

Coding is the process of whereby the physical design specifications created by the analysis team turned into working computer code by the programming team.

Testing

Once the coding process is begin and proceed in parallel, as each program module can be tested.

Installation

Installation is the process during which the current system is replaced by the new system. This includes conversion of existing data, software, and documentation and work procedures to those consistent with the new system.

Documentation

It is result from the installation process, user guides provides the information of how the use the system and its flow.

Training and Support

Training plan is a strategy for training user so they quickly learn to the new system. The development of the training plan probably began earlier in the project. The best-suited application package to develop the system is visual java under windows environment.

SYSTEM MODELS

- Secrete Key generation
- Head Cluster determination
- Performance Measurement

3.1Secrete Key Generation

The input messages can be in any digital form, and are often treated as a bit stream. The input message is then converted into encrypted form after a bit permutation is done on the message. Two level of encryption has been done on the message to raise the steganographic security level. This encrypted message generates the secret key, which may be called a message enabled key. A pseudo random number generator is used to locate the embedding positions of the message bits randomly. Before embedding a password protection is also necessary to raise another level of security. Stego image has been segmented using normalized cut method at the sender side and each cut /segmented objects are transmitted individually to the receiver, which are required for reassembly and feature matching at the receiver side. At the receiver side, cuts/segmented objects of the stego image are reassembled and tested for a specific feature.

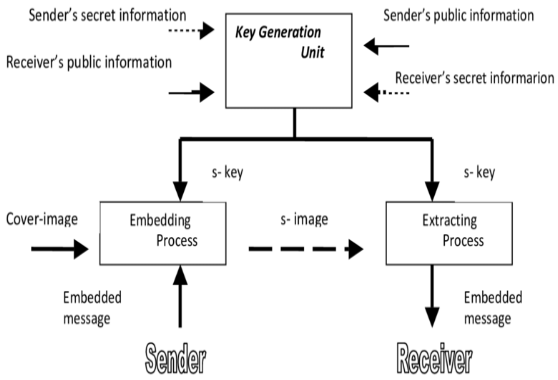


Fig. 5: System Flow Diagram of Secret Key Unit

3.2 Head Cluster Determination

The cluster heads can be selected randomly or based on one or more criteria. Selection of cluster head largely affects WSNs lifetime. Ideal cluster head is the one which has the highest residual energy, the maximum number of neighbor nodes, and the smallest distance from base station.

- The first step is that the clusters are created based on color pattern matching. An exhaustive search is conducted to pair up the same color pixels within a cluster. Each pixel which is similar in color within threshold value is included in a cluster.
- After the clusters are created, their color table is created based on color clusters.
- As it is very rare that two or more clusters can be of same size, therefore, the cluster which contains the largest number of pixels is chosen so that embedding space should be as large as possible.
- It is useful when embedding a larger message. After the message is embedded into the cluster, the stego-image generated can be sent over the internet in a secure way.

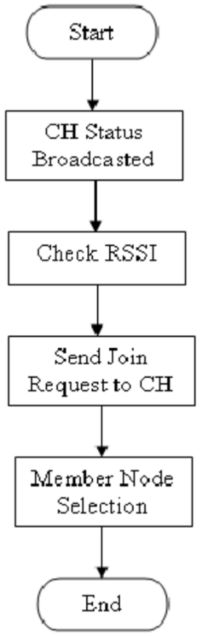


Fig. 6: System Flow Diagram of Head Cluster Selection

3.3 Performance Measurement

First we need to create MIMO model for Clock Syncronization method. Then, Steganography method has to be performed during data communication in the sensor network. It is done to avoid malfunction and mishandling of data and system usage. Thus a secrete key is generated at source end for the data to be transmitted. The secrete key is encoded and transmitted in the channel. At the receiving end, the secrete key is decoded and the received data signal is stored in the desired node.

For our simulation procedure, we have been specific about certain feature parameters as mentioned below to enable hassle free simulation.

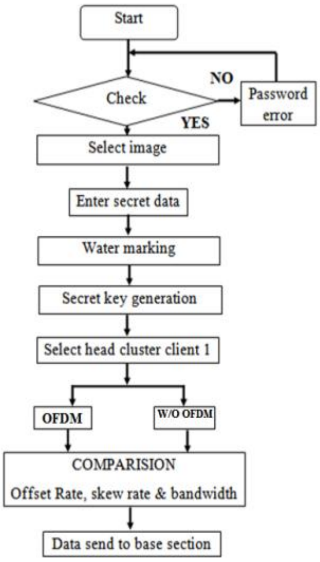
GUI design format for the concept

PASSWORD : 12345

I/P DATA (eg., Hai)

RDWT technique to embedded data in the image (Steganography process)

These parameters were holed for the whole process of experimentation with the protocol.



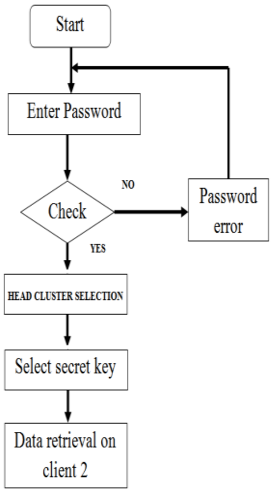


Fig. 7: System Flow Diagram of Source **Fig. 8: System Flow Diagram of Destination**

The performance of the proposed algorithm is evaluated through MATLAB simulator. Performance metrics values are utilized in the simulations for performance comparison are ,

- PAPR average transmit
- Skew Rate
- Offset Value
- Error Signal
- PAPR – PCV

IV. RESULT AND DISCUSSION

At first, GUI for the concept has been designed. It consists of several nodes at source and destination along with a Base Station..

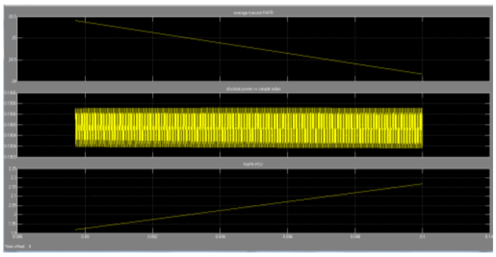


Fig. 9: Power Analysis

The network performance of MIMO system with and without OFDM using Clock Synchronization for Wireless Sensor Network was analyzed.

Without OFDM

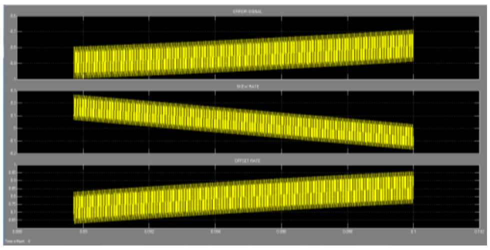


Fig. 10: Signal Strength at Source

With OFDM

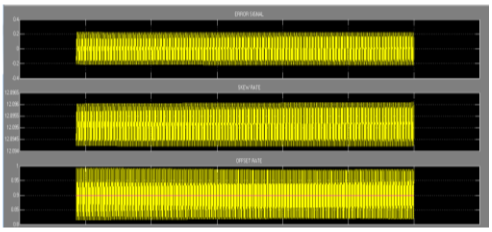


Fig. 11: Signal Strength at Destination

V. CONCLUSION AND FUTURE ENHANCEMENT

In this project, the proposed OFDM method for clock synchronization in wireless sensor network in MIMO system is implemented. Thus the proposed OFDM method for clock synchronization is a consensus based method, wherein the nodes agree to synchronize to the OFDM of CTPs of the nodes. The synchronization was carried at two levels.

At the first level, the nodes within a cluster gets synchronized and in the second level the cluster heads get synchronized. Having two level of synchronization reduces the communication and computation overhead. The proposed method is simple to implement. The nodes synchronize to a common time without changing their CTP. They use their own CTP to calculate network needs and makes changes up to reach network synchronization. The convergence time for the entire network is Ct. The clock offset and clock skew among the nodes is removed simultaneously. Further research would be focused on calculating Ct in the presence of noise and varying propagation delay between the nodes.

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