# Physical Performance and Cross Layer design for Wireless Mesh Networks

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## Abstract

*Wireless mesh networks (WMNs) are an alternative technology for last-mile broadband Internet access that can support broadband services. However, for a WMN to be all it can be, considerable research efforts are still needed. In WMNs, the Orthogonal Frequency Division Multiplexing (OFDM) system is chose to provide the better performance at the physical layer design. OFDM is very tolerant to ISI and it's spectrally efficient. OFDM also very susceptible to phase and frequency offsets. This paper presents the physical layer design of an OFDM system for wireless mesh networking.*

## 1. Introduction

Wireless mesh networks (WMNs) play a significant role for broadband access with ubiquitous coverage [1] – [6]. In transmission medium that used in networking backhaul Access Points (APs) is radio, the WMN is not only easy and cost effective deployment, but also have good reliability, market coverage and good scalability in coverage area and capacity. WMN aims to provide reliable high throughput network connectivity to wireless users [7]. Mesh network topology is one of the key network architectures in which devices are connected with many redundant interconnections between network nodes such as routers and switches. In a mesh topology if any cable or node fails, there are many other ways for two nodes to communicate.

In physical layer design, Orthogonal Frequency Division Multiplexing (OFDM) has become an attractive technique and gained more popularity recently in wireless mesh networks. The OFDM system is selected because its good properties such as tolerance to inter-symbol interference (ISI) and good spectral efficiency.

Recently, in an effort to improve the performance of wireless networks, there has been interest in protocols that rely on interactions between different layers [8]. The concept and analysis of cross layer design plays an important role in wireless systems. Through the cross layer design, it is necessary to consider both the physical layer effect and the medium access control (MAC) protocol efficiency and system level information to achieve high throughput.

## 2. Wireless Mesh Networking

The deployment of wireless mesh networks (WMNs) in order to provide connectivity among communities is becoming increasingly popular. The WMNs consists of mesh routers and mesh clients [9] where the mesh routers are stationary nodes that have enhanced capabilities in comparison to mesh clients such as higher transmit power, multiple receive/transmit antenna, unlimited power supply etc. The mesh clients are the wireless devices to which the WMN provides connectivity. The wireless mesh networks interconnection is shown in Figure 1.

If a mesh client needs to communicate with a node (another mesh client or a gateway) that is not within its communication range, the mesh client forwards the packet to its nearest mesh router. The packet is then forwarded over the mesh router backbone over multiple hops, according to the underlying routing protocol, until it reaches a mesh router that can forward to the destination node. The standards that used in WMNs are

IEEE 802.11 g for 2.4 GHz. This standard is depends on mesh routers (Linksys product is chosen).

**Figure 1: A wireless mesh network interconnection [9].**

The characteristics of WMNs are multi-hop wireless network, support for ad hoc networking, and capability of self-forming, self-healing, and self-organization. Besides, WMNs compatibility and interoperability with existing wireless networks. Many applications on wireless mesh networks that uses today such as broadband home networking, community and neighborhood networks, enterprise networking, building automation and so on [9].

While designing WMNs, it is important that how the packets sent, signal-to-noise ratio, bit error rate and symbol error rate at physical layer. For Medium Access Control (MAC) Layer design, it is important to understand the throughput and delay based of the terms of networks parameter. The get the better performance in WMNs, the cross layer for physical and MAC layer design must done to maximize the throughput, delay and bit error rate.

## 3. Physical Layer Technology

Recently, Orthogonal Frequency Division Multiplexing (OFDM) model is used in WMNs for physical layer design. OFDM technique based on multi carrier modulation (MCM) and frequency division multiplexing (FDM). OFDM can be considered as a modulation or multiplexing method. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers [10].

*A. Transmitted signal*

In communication system, the system sends K=lc bits of information in every T seconds througl channel for a data rate of R=K/T bits per second (b

When messages are sent sequentially, the transn signal becomes a sequence of the corresponding a signals over each time interval [kT,(k+1)T):

$$s(t)=\sum_k s_i(t-kT), \quad (1)$$

where $s_i(t)$ is a baseband or passband analog s corresponding to the message $m_i$ designated fo transmission interval [kT,(k+1)T). All s processing is made in the frequency domain and b transmission the signal is transformed to the domain [11].

*B. OFDM System*

The OFDM symbol is created in the digital do before transmission. Serial data is first mapped i common methods e.g BPSK, QPSK or QAM. figure shows the basic of OFDM system.

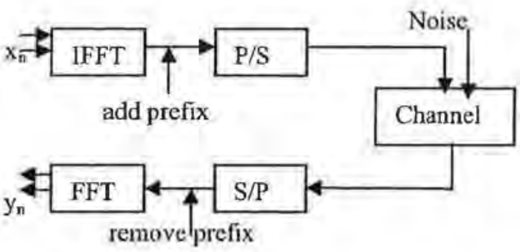


Figure 2: Basic OFDM System

IFFT = Inverse Fast Fourier Transform
FFT = Fast Fourier Transform
P/S = Parallel to Serial
S/P = Serial to Parallel

This data stream is converted into N parallel strc which are to be converted into an OFDM symbol. OFDM symbol consists of N data symbols, carried subcarrier.

IFFT block is used at the transmitter to transforn data sequence X(k) of length N into time domain signal {x(n)}with the following equation:

$$x(n) = \text{IFFT}\ \{X(k)\} \qquad n=0,1,2,..N\text{-}1$$

$$= \sum_{k=0}^{N-1} X(k) e^{\frac{j2\pi kn}{N}}$$

(2)

N=FFT length

Cyclic prefix includes the cyclically extended part of OFDM symbol in order to eliminate interference (ICI). The cyclic prefix allows multipath components to fade away before the information is extracted from the next symbol.

The resultant OFDM symbol is given as follows:

$$x_f(n) = \begin{cases} x(N+n), & n=-N_g,-N_g+1,\ldots,-1 \\ x(n), & n=0,1,\ldots,N-1 \end{cases}$$

(3)

where $N_g$ is the length of the guard interval. The transmitted signal $x_f(n)$ passes through the frequency selective time varying fading channel with additive white gaussian noise. The received signal is given by:

$$y_f(n) = x_f(n) \otimes h(n) + w(n)$$

(4)

Where w(n) is Additive White Gaussian Noise (AWGN) and h(n) is the impulse response. Channel is assumed to be frequency selective fading, so it is considered to be constant during one OFDM symbol.

At the receiver, cyclic prefix is removed:

$$y_f(n) = \begin{cases} y_f(n), & for -N_g \le n \le N-1 \\ y_f(n+N_g) & n=0,1,\ldots,N-1 \end{cases}$$

(5)

Then y(n) is sent to FFT block for the following operation:

$$Y(k) = \text{FFT}\{y(n)\} \qquad (6)$$

$$= \frac{1}{N} \sum_{n=0}^{N-1} y(n) e^{-j\left(\frac{2\pi kn}{N}\right)}$$

*C. Channel*

The multipath fading is suitable used in OFDM system for wireless mesh networks in channel. Multipath is due to the constructive and destructive combination of randomly delayed, reflected, scattered, and diffracted signal components.

## 4. Medium Access Control Layer Design

Each station and access point on an 802.11 network implements the MAC sublayer service. The MAC sublayer provides these primary wireless network operations to wireless stations that accessing the wireless medium, joining a network, authentication and privacy. The MAC layer decides in a distributed manner on how the offered bandwidth is shared among all stations [12].

The characteristics of MAC layer are the MAC layer is concerned with more than one hop communication in WMN. Besides, MAC layer works for multipoint to multipoint and network self organization that is needed for better collaboration between neighboring nodes and nodes in multi-hop distances. After receiving each packet a mesh router counts up a random back off timer.

In wireless mesh networks, the better performance at MAC layer design is Carrier Sense Multiple Access / Carrier Avoidance (CSMA/CA). Many researchers used CSMA/CA in wireless mesh networking. The mechanism of CSMA/CA must be enhanced if it to be running in WMNs. W. Liu, L. Wang and Y. Lin suggested that the MAC layer goodput had been calculated in analytical model for the IEEE 802.11a WLAN in the Nakagami fading channel, while incorporating the effects of channel estimation, delay spread and signal detection scheme in physical layer [13].

## 5. Cross Layer Design (Physical + Mac)

The layering principle of network design has served for some 30 years as a convenient means of isolating the functions of the different conceptual layers for the purposes of modular design and teaching the principles of complex networking systems [14]. Cross layer design aims at coupling the functionality of network layers, with the goal of boosting system-wide performance [14]. The cross layer between physical and MAC layer design occurred before and after the modulation. The trend is more evident at the interface between the physical and MAC layers [14].

Designing efficient mesh networking protocols is critical [6]. Without some modifications at the MAC or physical layer, however, this approach is doomed to system inefficiencies and possible total collapse in large network, because of MAC layer problems [6]. In this case, the MAC and routing layers are important to design in the network. Besides, the physical layer should also be designed from scratch. That is ideal solution because in mesh networks, the design must include maximized system throughput and make challenges [6].

## 6. Conclusions

As a conclusion, there have many open research and challenges in physical layer for wireless mesh networks. The physical layer, higher-layer protocols, especially MAC protocols provided the best utilize for advanced features need to work interactively with the physical layer. Consequently, some components in the physical layer must be designed in a way that higher layers can access or control them [9]. The OFDM system is chose in wireless mesh networks for get the better performance. An attempt to joint physical MAC layer design for wireless mesh networks will be done to improve the throughput, capacity and latency, in the future.

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