# Design and Implementation of Wi-Fi Medium Access Control Layer for Transmitter with VHDL

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**Abstract:** ***For the wireless communication in radio frequency range, IEEE 802.11 is one of the many standard available. IEEE 802.11b defines the Medium Access Control Layer [MAC] for wireless local area networks. The wireless local area network, WLAN is dominated by IEEE 802.11 standard. It becomes one of the main focuses of the WLAN research. Now most of the ongoing research projects are simulation based as their actual hardware implementation is not cost effective. The main core of the IEEE 802.11b standard is the CSMA\CA, Physical and MAC layers. But only MAC layer for transmitter is modeled in this paper using the VHDL. The VHDL (Very High Speed Hardware Description LANguage) is defined in IEEE as a tool of creation of electronics system because it supports the development verification synthesis and testing of hardware design, the communication of hardware design data and the maintenance, modification and procurement of hardware. It is a common LANguage for electronics design and development prototyping. The main purpose of the IEEE 802.11 standard is to provide wireless connectivity to devices that require a faster installation, such as Laptops, PDA's or generally mobile devices inside a WLAN. MAC procedures are defined here for accessing the physical medium, which can be infrared or radio frequency. Here Wi-Fi MAC Transmitter module is divided in to 5 blocks i.e. Data Unit Interface block, Controller block, Pay Load Data Storage block, MAC Header Register block, Data Processing block. In this paper, we are considering only two blocks i.e. Payload Data Storage block & Data Processing block.***

**Keywords:** Wi-Fi, Technology, transmission, control layer, implementation

## 1. Introduction

Due to technology advancement in the 21st century, wireless communication had been most popular choice of communication. More and more people are turning to wireless due to the convenience of mobility.

An 802.11 LAN is based on a cellular architecture where the system is subdivided in to cells, where each cell [called basic service set or BSS] is controlled by a base station [called access point, or in short ap]. Even Though that a wireless LAN may be formed by a single Cell, with a single access point [can also work without an access point], most installations will be formed by several cells, where the access points are connected through some kind of back bone [called distribution system or ds], typically Ethernet, and in some cases wireless itself. The whole interconnected wireless LAN Including the different cells, their respective access points and the distribution system, is seen to the upper layers of the OSI model, as a single 802 network and is called in the standard as extended service set [ESS]. The standard also defines the concept of a portal, a PORTAL is a device that interconnects an 802.11 and another 802 LAN .However, all is not prefect in the WLAN world. Offering nominal bit rates of 11mbps [802.11b] and 54mbps (802.11a and 802.11g) the effective throughputs are actually much lower-owing to packet collisions, protocol overhead, and interference in the Increasingly congested unlicensed bands at 2.4ghz and 5ghz. Furthermore, operation in these bands entails a strict regulatory transmit power constraint, thus limiting range and even bit rates beyond a certain distance. A wireless LAN (WLAN) is a data transmission system designed to provide location-independent network access between computing devices by using radio waves rather than a cable infrastructure. WLAN utilizes spread-spectrum technology based on radio waves to enable communication between devices in a limited area, also known as the basic service set. This gives users the mobility to move around within a broad coverage area and still be connected to the network. For the home user, wireless has become popular due to ease of installation, and location freedom with the gaining popularity of laptops. The majority of future wireless LAN growth is expected in healthcare facilities, educational institutions, and corporate enterprise office spaces.

### 1.1 Project Overview

Wi-Fi stands for Wireless Fidelity. Wi-Fi is based on the IEEE 802.11 family of standards and is primarily a local area networking (LAN) technology designed to provide in-building broadband coverage. Wi-Fi is a universal wireless networking technology that utilizes radio frequencies to transfer data. Wi-Fi is more commonly used in point-to-multipoint (PMP) environments to allow extended network connectivity of multiple portable devices such as laptops, telephones, or PDAs. Wi-Fi also allows connectivity in point-to-point (P2P) mode, which enables devices to directly connect and communicate to each other. Wi-Fi networks operate in the unlicensed 2.4 radio bands, with an 11 Mbps (802.11b) or 54 Mbps (802.11a) data rate, respectively. There are three most important items which makes Wi-Fi working in your laptop or desktop. These are:

- Radio Signals
- Wi-Fi Card which fits in your laptop or computer.
- Hotspots which create Wi-Fi Network.

Wi-Fi also can be used to create a wireless mesh network, which is a decentralized, reliable, resilient, and relatively inexpensive solution that can support areas of lacking or destroyed network infrastructure (e.g., connectivity for a field office or emergency command center).

## 2. History

VHDL was originally developed at the behest of the U.S Department of Defense in order to document the behavior of the ASICs that supplier companies were including in equipment. That is to say, VHDL was developed as an alternative to huge, complex manuals which were subject to implementation-specific details. The idea of being able to simulate this documentation was so obviously attractive those logic simulators were developed that could read the VHDL files. The next step was the development of logic synthesis tools that read the VHDL, and output a definition of the physical implementation of the circuit. Due to the Department of Defense requiring as much of the syntax as possible to be based on Ada, in order to avoid re-inventing concepts that had already been thoroughly tested in the development of Ada, VHDL borrows heavily from the Ada programming language in both concepts and syntax. The initial version of VHDL, designed to IEEE standard 1076-1987, included a wide range of data types, including numerical(integer and real),logical(bit and boolean), character and time plus arrays of bit called bit vector and of character called string. A problem not solved by this edition, however, was "multi-valued logic", where a signal's drive strength (none, weak or strong) and unknown values are also considered. This required IEEE standard 1164, which defined the 9-value logic types: scalar std_ulogic and its vector version std_ulogic_vector. The updated IEEE 1076, in 1993, made the syntax more consistent, allowed more flexibility in naming, extended the character type to allow ISO-8859-1 printable characters, added the xnor operator, etc.

Minor changes in the standard (2000 and 2002) added the idea of protected types (similar to the concept of class in C++) and removed some restrictions from port mapping rules. In addition to IEEE standard 1164, several child standards were introduced to extend functionality of the language. IEEE standard 1076.2 added better handling of real and complex data types. IEEE standard 1076.3 introduced signed and unsigned types to facilitate arithmetical operations on vectors. IEEE standard 1076.1 (known as VHDL-AMS) provided analog and mixed-signal circuit design extensions. Some other standards support wider use of VHDL, notably VITAL (VHDL Initiative Towards ASIC Libraries) and microwave circuit design extensions. In June 2006, the VHDL Technical Committee of Accellera (delegated by IEEE to work on the next update of the standard) approved so called Draft 3.0 of VHDL-2006. While maintaining full compatibility with older versions, this proposed standard provides numerous extensions that make writing and managing VHDL code easier. Key changes include incorporation of child standards (1164, 1076.2, 1076.3) into the main 1076 standard, an extended set of operators, more flexible syntax of case and generate statements, incorporation of VHPI (interface to C/C++ languages) and a subset of PSL (Property Specification Language). These changes should improve quality of synthesizable VHDL code, make testbenches more flexible, and allow wider use of VHDL for system-level descriptions.

In February 2008, Accellera approved VHDL 4.0 also informally known as VHDL 2008, which addressed more than 90 issues discovered during the trial period for version 3.0 and includes enhanced generic types. In 2008, Accellera released VHDL 4.0 to the IEEE for balloting for inclusion in IEEE 1076-2008. The VHDL standard IEEE 1076-2008 was published in January 2009.

### 2.1 Benefits of Wireless Fidelity

The popularity of wireless LANs is a testament primarily to their convenience, cost efficiency, and ease of integration with other networks and network components.

The benefits of Wi-Fi include:

1) **Convenience:** The wireless nature of such networks allows users to access network resources from nearly any convenient location within their primary networking environment (home or office).
2) **Mobility:** With the emergence of public wireless networks, users can access the internet even outside their normal work environment.
3) **Deployment:** Initial setup of an infrastructure-based wireless network requires little more than a single access point
4) **Expandability:** Wireless networks can serve a suddenly-increased number of clients with the existing equipment. In a wired network, additional clients would require additional wiring.
5) **Cost:** Wi-Fi chipset pricing continues to come down, making Wi-Fi a very economical networking option and driving inclusion of Wi-Fi in an ever-widening array of devices.

### 2.2 Disadvantages of Wireless Fidelity

For a given networking situation, wireless LANs have following limitations.

1) **Security** - Security concerns have held back Wi-Fi adoption in the corporate world. It can be easy to crack the current security technology, known as wired equivalent privacy (WEP), used in most Wi-Fi connections. A hacker can break into a Wi-Fi network using readily available materials and software.
2) **Range** - The typical range of a common 802.11b Wi-Fi network is on the order of tens of meters. It will be insufficient in a larger structure.
3) **Reliability**- Like any other radio frequency transmission, wireless networking signals are subject to a wide variety of interference, as well as complex propagation effects such as multipath.
4) **Speed**- The speed on most wireless networks (typically 1-108 Mbps) is reasonably slow compared to the slowest common wired networks.
5) **Energy** - Power consumption is fairly high compared to some other standards, making battery life and heat a concern. To overcome these disadvantages of Wi-Fi we are designing controller which controls the accessing of medium at the transmitter of Wi-Fi using IEEE 802.11 standards. For computer networks, a seven layer –layer ISO (International Standards Organization) OSI (Open Systems Interconnection) reference model is widely used. The communication sub network can be described by the lower three layers (i.e., physical, data link, and network layers). Existing LAN’s, MANs (metropolitan

area networks) do utilize broadcast channels rather than point-to-point channels for information transmission. Therefore, a simple modification of OSI model is done by adding the so called MAC (medium access control) sub layer in data link layer. The MAC sub layer protocols, usually known as the multiple access protocols, are primarily a set of rules that communicating terminals need to follow, and these are assumed to be agreed upon a priori.

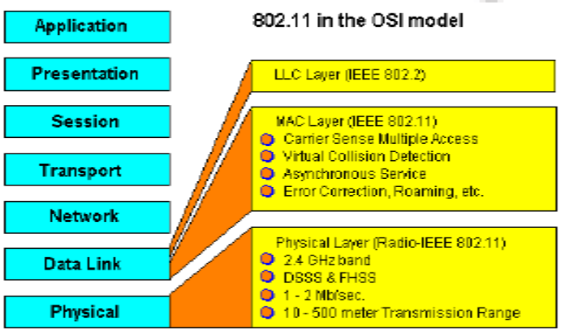



**Figure 2:** 802.11 OSI model

### 2.3 802.11 Operating Modes

The 802.11 standard defines two modes: Infrastructure mode and ad hoc mode. In infrastructure mode, the wireless network consists of at least one access point connected to the wired network infrastructure and a set of wireless end stations. This configuration is called a Basic Service Set (BSS). An Extended Service Set (ESS) is a set of two or more BSSs forming a single sub network. Ad hoc mode (also called peer-to-peer) mode or an Independent Basic Service Set, or IBSS) is simply a set of 802.11 wireless stations that communicate directly with one another without using an access point or any connection to a wired network.

### 2.4 Important WLAN Standards

IEEE 802.11 standard is of Wireless LAN (WLAN) standards. IEEE 802.11b defines the Medium Access Control layer [MAC] for Wi-Fi to avoid collisions. In general, the MAC Layer manages and maintains communications between 802.11 stations (radio network cards and access points) by coordinating access to a shared radio channel and utilizing protocols that enhance communications over a wireless medium.

## 3. MAC layer

The MAC layer is a section of the OSI Network Model. The OSI model manages data sent and received by the network access hardware within a computer or other network ready device. The network model is a diagram showing how data flows from the user of one PC through the model to arrive at another PCs user interface. In OSI model MAC layer is between data link layer and physical layer which provide reliable mechanism for exchanging traction packets [data control and management] on the communications channel through physical layer MAC layer performs the transmit functions it should generate various MAC address .generation of 16 bit hec for header and 32 bit CRC for payload data.crc and hec generation for payload. FIFO buffer interface for transmitter serializing the data using byte to bit converter. MAC transmitter controller state machine implementation.MAC layer performs functions like on transmission assemble data in to a frame with address and error detection fields Govern access to the LAN transmission medium .physical layer performs functions like;

- Encoding/decoding
- Preamble generation
- Bit transmission/reception
- Includes specification

Wi-Fi wireless fidelity 802.11 family of standards for LAN Wi-Fi is designed for local networks which are in short range but Wi-Fi achieves greater than 10 Mb /sec throughput for a user in many circumstances. Currently Wi-Fi carries more user data than any other wireless technology .evolution is to get further faster and at lower power consumption. Wi-Fi is a commercially success full broad band service .it is an upstart wireless LAN technology under the 80p2.11 umbrella have leap frogged towards cellular and other efforts towards broad band wireless.

### 3.1 802.11 MAC Layer Functions

The following summarizes primary 802.11 MAC functions, especially as they relate to infrastructure wireless LANs:

#### 3.1.1 Authentication
Authentication is the process of proving identity, and the 802.11 standard specifies two forms: Open system authentication and shared key authentication. In this paper we use shared key authentication only. Shared key authentication is a process that bases authentication on whether the authenticating device has the correct WEP (wired equivalent privacy) key.

#### 3.1.2 Association
Once authenticated, the radio NIC must associate with the access point before sending data frames. Association is necessary to synchronize the radio NIC and access point with important information, such as supported data rates.

#### 3.1.3 RTS/CTS
The optional request-to send and clear-to-send (RTS/CTS) function allows the access point to control use of the medium for stations activating RTS/CTS. WEP: With the optional WEP enabled, the wireless NIC will encrypt the body (not header) of each frame before transmission using a common key, and the receiving station will decrypt the frame upon receipt using the common key. The 802.11 standard specifies a 40-bit key and no key distribution method, which makes 802.11 wireless LANs vulnerable to eavesdroppers.

#### 3.1.4 Fragmentation
The optional fragmentation function enables an 802.11 station to divide data packets into smaller frames. This is done to avoid needing to retransmit large frames in the presence of RF interference. The bits errors resulting from RF interference are likely to affect a single frame, and it requires less overhead to retransmit a smaller frame rather than a larger one. As with RTS/CTS, users can generally set a maximum frame length threshold whereby the radio NIC

will activate fragmentation. If the frame size is larger than the threshold, the radio NIC will break the packet into multiple frames, with each other.

The main objective of the IEEE 802.11 is standard the CSMA/CA Physical and MAC layer for transmitter and receiver is modeled in this paper. The VHDL (Very High Speed Hardware Description Language) is defined in IEEE as a tool of creation of electronics systems because it supports the development verification synthesis and testing. The main core of the IEEE

802.1 lb standard are an 802.11 and another 802 LAN [3]. The CSMA\CA, Physical and MAC layers, but only MAC However, all is not prefect in the WLAN world. Layer for transmitter is modeled in this paper using the Offering nominal bit rates of 11Mbps [802.1 lb] and VHDL. The VHDL (Very High Speed Hardware 54Mbps (802.1la and 802.11g) the effective throughputs Description Language ) is defined in IEEE as a tool of are actually much lower-owing to packet collisions, creation of electronics system because it supports the protocol overhead , and interference in the increasingly development , verification , synthesis and testing of congested unlicensed bands at 2.4GHz and 5GHz. Further hardware design, the communication of hardware design more, operation in these bands entails a strict regulatory data and the maintenance, modification and procurement transmit power constraint, thus limiting range and even bit of hardware. It is a common language for electronics rates beyond a certain distance design and development prototyping A Users expect Internet connectivity wherever they travel and many of their devices, such as iPods and wireless cameras, rely on local area Wi-Fi access points (APs) to obtain connectivity. Even smart phone users may employ Wi-Fi instead of 3G and WiMAX to improve the performance of bandwidth intensive applications or to avoid data charges. Fortunately, there is often a large selection of commercial APs to choose from. For example, JiWire [6], a hotspot directory, reports 395 to 1,071 commercial AP the designed data link layer is capable of MAC layer and physical layer .the data link layer communicates with the other three layers .the layers designed are capable of transmitting 1 and 2 mbits \sec i.e. frequency hopping spread spectrum in the 2,4 GHz band and infrared .beyond the standard functionality usually performed by MAC layers the 802.11 MAC performance .the protocols consisting of fragmentation ,packet retransmission and acknowledgements. The MAC layer defines two access methods the distribution coordination function and point coordination function.

## 4. Wi-Fi MAC Transmitter

Wi-Fi MAC Transmitter provides wireless connectivity to devices that require a faster installation, such as Laptops, PDA's or generally mobile devices inside a WLAN. MAC procedures are defined here for accessing the physical medium, which can be infrared or radio frequency. Here Wi-Fi MAC Transmitter module is divided in to 5 blocks i.e. Data Unit Interface block, Controller block, Pay Load Data Storage block, MAC Header Register block, Data Processing block. In this paper, we are considering only two blocks i.e. Payload Data Storage block & Data Processing block..

### 4.1 Medium Access Basics

IEEE 802.11 wireless LANs use a media access control protocol called Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). Wi-Fi systems are half duplex shared media configurations where all stations transmit and receive on the same radio channel. The fundamental problem this creates in a radio system is that a station cannot hear while it is sending, and hence it impossible to detect a collision. Because of this, the developers of the 802.11 specifications came up with a collision avoidance mechanism called the Distributed Control Function (DCF). According to DCF, A Wi-Fi station will transmit only if it thinks the channel is clear. All transmissions are acknowledged, so if a station does not receive an acknowledgement, it assumes a collision occurred and retries after a random waiting interval. The incidence of collisions will increase as the traffic increases or in situations where mobile stations cannot hear each other.

### 4.2 Carrier -Sensing and Network Allocation Vector

Carrier sensing is used to determine if the medium is available or not. As a condition to accessing the medium, the MAC Layer checks the value of its network allocation vector (NAV), which is a counter resident at each station that represents the amount of time that the previous frame needs to send its frame. The NAV must be zero before a station can attempt to send a frame. Prior to transmitting a frame, a station calculates the amount of time necessary to send the frame based on the frame's length and data rate. The station places a value representing this time in the duration field in the header of the frame. When stations receive the frame, they examine this duration field value and use it as the basis for setting their corresponding NAVs. This process reserves the medium for the sending station.

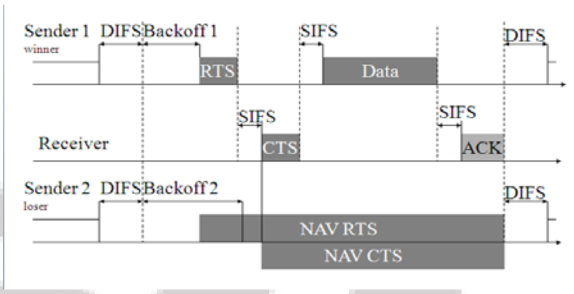



**Figure 3:** Using NAV for Virtual Carrier

### 4.3 Short Inter frame Space (SIFS)

The SIFS is used for the highest-priority transmissions, such as RTS/CTS Frames and positive acknowledgements. High-priority transmissions can begin once the SIFS has elapsed .Once these high priority transmission begin, the medium becomes busy, and so frames transmitted after SIFS has elapsed have priority over frames that can be transmitted only after long intervals.

### 4.4 DCF Inter frame space (DIFS)

The DIFS is the minimum medium idle time for contention based services. Stations may have immediate access to the medium if it has been for a period longer than the DIFS.

### 4.5 Exponential Back Off Algorithm

Backoff is a well known method to resolve contention between different stations willing to access the medium, the method requires each station to choose a Random Number (n) between 0 and a given number, and wait for this number of Slots before accessing the medium, always checking whether a different station has accessed the medium before. The Slot Time is defined in such a way that a station will always be capable of determining if other station has accessed the medium at the beginning of the previous slot. This reduces the collision probability by half. Exponential Backoff means that each time the station chooses a slot and happens to collide; it will increase the maximum number for the random selection exponentially. The 802.11 standard defines an Exponential Backoff Algorithm, which must be executed in the following cases:

(a)If when the station senses the medium before the first transmission of a packet and the medium is busy,
(b) After each retransmission, and
(c) After a successful transmission
(d) The only case when this mechanism is not used is when the station decides to transmit

We are dealing with only 802.11 MAC layer for this paper using 802.11b standard due to its ease of operating standards. The following figure shows a schematic of the access mechanism:

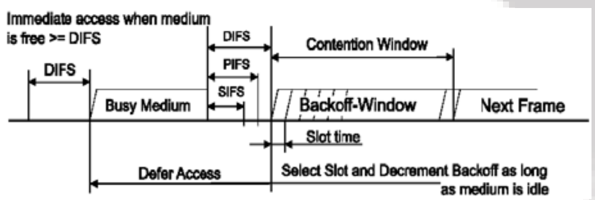



**Figure 4:** Backoff Access Mechanism

The transmitter block is Fig 4.6 Block diagram of transmitter divided in to five parts as shown in fig 4 and only two blocks are considered for VHDL simulation. These are Payload Data Storage block & Data Processing block.

## 5. Low Chart

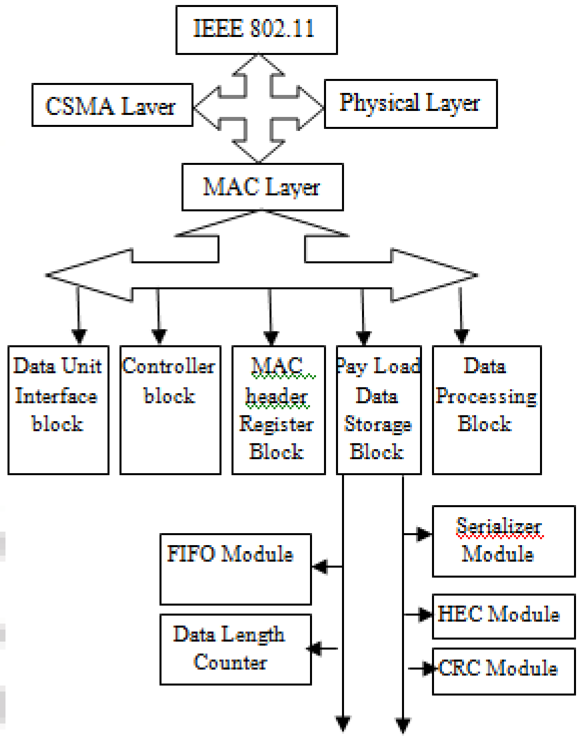
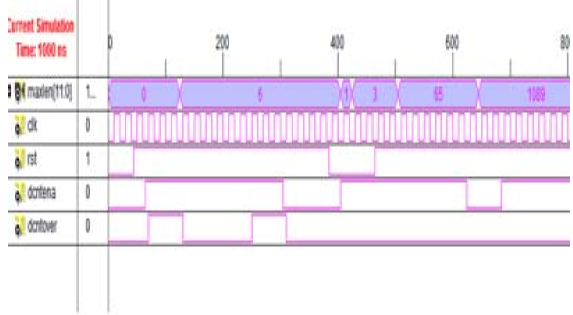


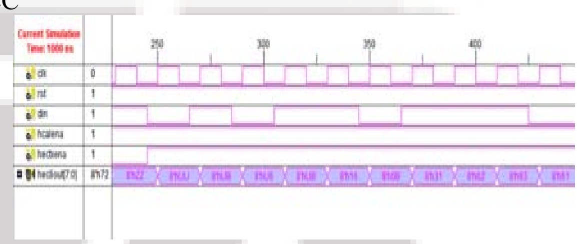

**Figure 4.6:** Block Diagram

## 6. Results

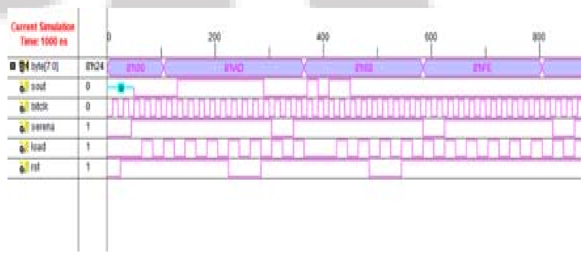
Data Length Counter



HEC



Parallel to Serial Converter



| |
|---|
| Logic Utilization: |
| Number of Slice Flip Flops :40 OUT OF 3840 1% |
| Number of 4 input LUTs :80 OUT OF 3840 2% |
| Number of IOs :13 |
| Logic Distribution: |
| Number of Slices :19 out of 33,280 1% |
| Number of Slices containing only related Logic :19 out of 19 100% |
| Number of Slices containing only unrelated Logic :0 out of 19 0% |
| Number of 4-input LUTs :8265 out of 88192 9% |
| Number of bonded IOBs :668 out of 784 85% |
| Number of GCLKs :2 out of 8 25% |
| Total equivalent gate count for design :1,417 |
| Additional JTAG gate count for IOBs :32,064 |
| Peak Memory Usage :396 MB |
| Total REAL time to MAP completion :33 s |
| Total CPU time to MAP completion :32 s |
| Timing Summary: |
| Maximum output required time after clock: 5.244NS ns |

**Table 1:** Design Implementation summary of the Medium Access Control Transmitter

## 7. Future Scope

In contrast to all other earlier generation steps, the 100Gbps technology is being realized for the first time for short transmission paths and first will be applied in computer centers for networking powerful computers. Interfaces defined for ranges 10km and 40km will first be geared for use in MAN. But whether in computer centers or in the MAN, 100Gbps technology will be introduced with parallel transmission and for that to happen, a workable concept is required for the integration of multi-lane system into the existing optical DWDM networks. In the next generation, it will be possible to use 100Gbps for serial transmissions. However, many development steps are necessary in order to achieve these goals. These include the cost-effective implementation of higher-level optical-modulation procedures (including polarization multiplexing) and the realization of the fast signal processors to smooth the way for coherent receivers.

While software defined radios is one direction towards obtaining more realistic insight into MAC layer performance, a further step is real-world experiments. Long-term experiments such as the one at Great Duck Island are the most realistic ones, but require a lot of engineering effort before research questions can be answered. Controlled indoor experiments are not as expressive as large-scale deployments but since real radio hardware is used, they do not suffer from the mistaken axioms. Ritter et al. have proposed to replace the batteries with high capacity capacitors, so-called GoldCaps, for the purpose of experimental validation of lifetime bounds for wireless sensor networks. This approach can also be used to compare the energy-efficiency of MAC protocols without waiting for the batteries of the sensor nodes to drain. While this approach has inherent drawbacks, e.g. it does not take the battery relaxation effect into account, results obtained using this approach is more realistic than simulations.

A system and method for media access control optimization for long distance wireless communication between an airborne platform and a surface base station is provided.

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