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DYNAMIC SPECTRUM ACCESS USING FILTERBANK MULTICARRIER

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Abstract: **Orthogonal frequency division multiplexing (OFDM), used for sharing the spectrum among different nodes in a dynamic spectrum access network, imposes tight timing and frequency synchronization requirements. The use of filter bank multicarrier (FBMC), understood alternative, for dynamic spectrum access and examine FBMC PHY layer, Data Link Layer, Network Layer, Transport Layer, Session Layer in reliably transmitting data packets at a very high rate, Next to understand the impact of FBMC beyond the PHY layer, distributed and adaptive medium access control (MAC) and Aggregation Algorithm protocol that coordinates data packet traffic among the different nodes in the network in a best-effort manner. The FBMC an order of magnitude performance improvement over OFDM in several aspects packet transmission delays, channel access delays, and effective data transmission rate available to each node in static, outdoor settings. Finally, through extensive simulations, we showed that FBMC outperforms OFDM with an order of magnitude improvement over large distances in vehicular networks. Finally, we also showed that in the case of multi hop vehicular networks, FBMC can achieve about smaller end-to-end packet delivery delays and relatively low packet drop probabilities in comparison to OFDM and also examine the use of FBMC in a multi hop vehicular network setup.**

Keywords: *Dynamic spectrum, filterbank multicarrier*

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM), which uses an orthogonal set of subcarriers, has been proposed for the purpose of sharing the different subsets of these subcarriers among nodes interested in dynamic spectrum access. However, OFDM imposes tight timing and frequency synchronization requirements among different nodes, which are very likely to be difficult to achieve in practice, especially when the nodes belong to different administrative entities. Any lack of synchronization can result in significant mutual interference among the signals of different transmitters. A somewhat lesser known and understood multicarrier communication system, filterbank multicarrier (FBMC), can overcome the above limitations of OFDM through the use of special transmitter and receiver pulse shaping filters, namely, the square root Nyquist filters [2]. Through the use of these filters, FBMC, in comparison to OFDM, promises more efficient spectrum utilization by minimizing interference across subcarriers.

A. OFDM

Orthogonal frequency-division multiplexing (OFDM) is a convenient and flexible choice to achieve high data-rate transmission over dispersive channels, without the need to resort to complicated equalization strategies. Orthogonal Frequency Division Multiplexing (OFDM) is a convenient technique for dealing with delay-spread (frequency-dependent) channels.

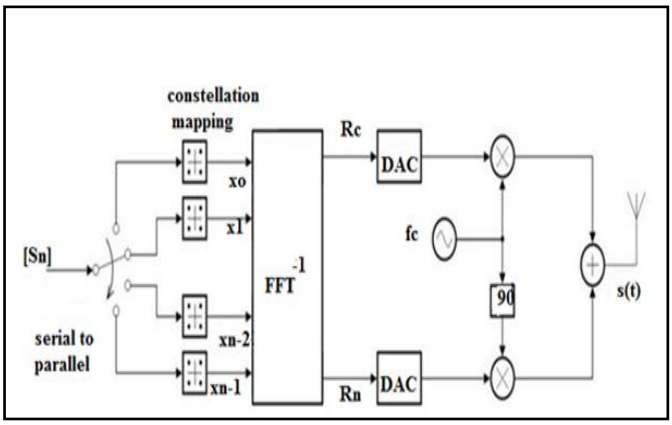

Fig 1 OFDM Transmitter

An essential feature of OFDM is the cyclic prefix a redundant periodic extension of the message-bearing sine waves, which for proper functioning must be at least as long as the delay-spread of the channel.

If the symbol interval can be made large compared with the cyclic prefix then the potential throughput of OFDM approaches the Shannon limit. Conversely if latency concerns, rapidly changing propagation environment, preclude using a long symbol interval.

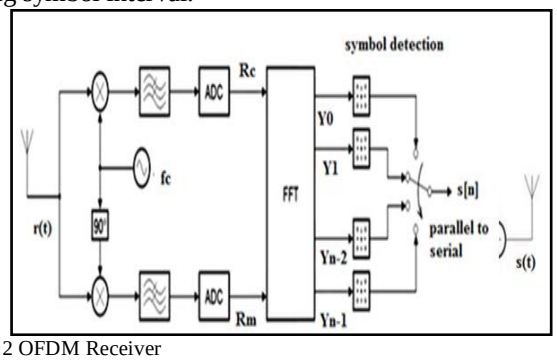

Fig 2 OFDM Receiver

II. LITERATURE REVIEW

A. Spectrum Pooling

Timo A. Weiss And Friedrich K. Jondral, Universität Karlsruhe proposed an innovative strategy for the enhancement of spectrum efficiency.

This represents the coexistence of two mobile radio systems within the same frequency range. It enables the secondary utilization of already licensed frequency bands as aimed at by several regulatory authorities worldwide. The goal of spectrum pooling is to enhance spectral efficiency by overlaying a new mobile radio system on an existing one without requiring any changes to the actual licensed system.

B. Synchronization Techniques for Orthogonal Frequency Division Multiple Access (OFDMA)

Michele Morelli, Member IEEE, C.-C. Jay Kuo, Fellow IEEE, and Man-On Pun, Member IEEE proposed the Synchronization Techniques for Orthogonal Frequency Division Multiple Access.

Synchronization represents one of the most challenging issues and plays a major role in the physical layer design. After quantifying the effects of synchronization errors on the system performance, we review some common methods to achieve timing and frequency alignment in a downlink transmission. We then consider the uplink case, where synchronization is made particularly difficult by the fact that each user's signal is characterized by different timing and frequency errors, and the base station has thus to estimate a relatively large number of unknown parameters. A second difficulty is related to how the estimated parameters must be employed to correct the uplink timing and frequency errors. The paper concludes with a comparison of the reviewed synchronization schemes in an OFDMA [8] scenario inspired by the IEEE 802.16 standard for wireless metropolitan area networks.

C. Packet Error Rate in OFDM-based Wireless LANs Operating in Frequency Selective Channels

Olufunmilola Awoniyi and Fouad A. Tobagi proposed the Packet Error Rate in OFDM-based Wireless LANs Operating in Frequency Selective Channels.

In general, packet loss is a function of packet error rate due to transmissions errors in the channel. Packet loss due to transmission errors in the wireless channel can significantly influence the performance of both data and packet voice applications in wireless networks. Packet loss leads to a reduction in TCP throughput for data and a loss in intelligibility for VoIP. the packet loss rate (PLR) of a TCP segment is given by,.

$$PLR = Pe|HNtr \quad (1)$$

It is based on frequency division multiplexing (FDM), which is a technology that uses multiple frequencies to simultaneously transmit multiple signals in parallel. Each signal has its own frequency range (sub-carrier) which is then modulated by data. Each subcarrier is separated by guard space to ensure that they do not overlap.

III. EXSISTING MODEL

A. Filterbank Multicarrier

The FBMC and OFDM simultaneously transmit[2] signals across several subcarriers. In each subcarrier, the information bits are encoded and transmitted as a series of pulses of different amplitudes and phases. Filter bank multicarrier based communication system offers a much higher performing alternative to OFDM for networks that dynamically share the spectrum among multiple nodes. To understand the impact of Filter bank multicarrier beyond the physical layer coordinates data packet traffic. FBMC can achieve about 20x smaller end to end data packet delivery delays relatively low packet drop probabilities.

B. System Model

Assume that there are multiple nodes, possibly belonging to different administrative entities that compete to utilize the shared frequency spectrum. Nodes belonging to different entities may be associated to different base stations while still sharing the same spectrum OFDM uses rectangular pulse shapes. It is widely used in practice including in the 802.11 Wi-Fi systems shows the power spectral density of an OFDM signal that is transmitted on subcarrier number 0.

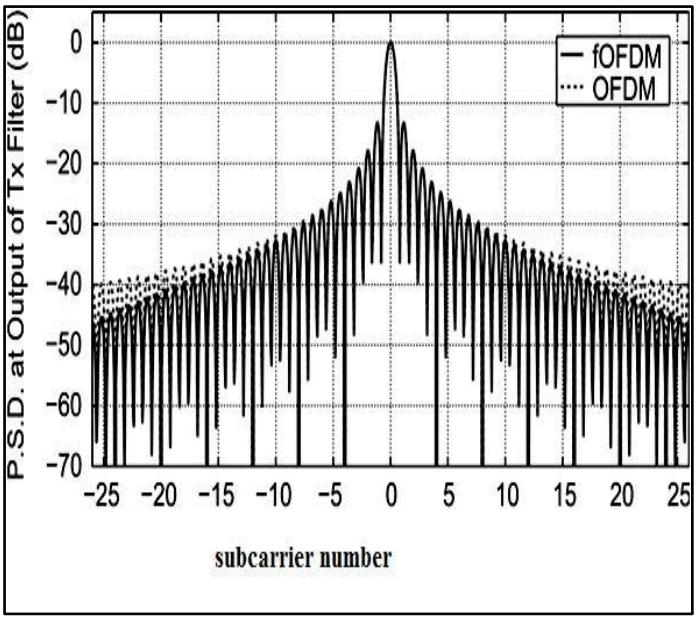

Fig 3 PSD of OFDM/fOFDM Signal

The first side lobes are just13 dB below the main peak, and the side lobes near either end of the channel are about 40 dB below the main peak. In 802.11a and other standards, it has been often proposed to replace the rectangular pulse of OFDM by a raised cosine pulse.

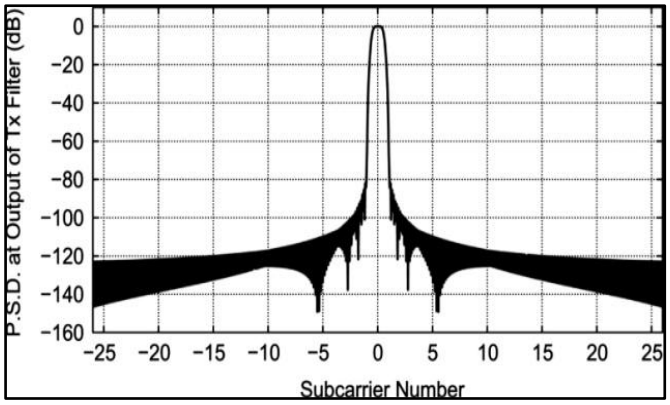

Fig 4 PSD of OFDM/fOFDM Signal

This modified OFDM is called Filtered-OFDM (fOFDM). The fOFDM exhibits lower side lobes when compared to OFDM. However, for the suggested roll-off factor in 802.11a (2.5%), this improvement is not significant. It compares the PSDs of OFDM and fOFDM. FBMC is 20%-40% more complex than OFDM. Moreover, when OFDM is applied to multiple access applications, it either performs poorly, one has to add significant complexity to the system to achieve perfect synchronization among different nodes or to apply computationally expensive multiple access interference (MAI) cancellation techniques to improve on its performance.

IV. PROPOSED METHOD

A. Methodology

While transmitting the data using FBMC, the speed will be increased in the other layers such as data link layer, network layer, transport layer and session layer. FBMC can achieve higher SINR, very low packet error rates and noise will be reduced. It can achieve above 20x smaller end to end data packet delivery delays.

B. FBMC beyond OFDM Applied in OSI Model

The FBMC beyond OFDM the PHY layer, Data Link Layer, Network Layer we devise a distributed and adaptive medium access control (MAC) protocol that coordinates data packet traffic among the different nodes in the network in a best-effort manner. Moreover, despite their much higher complexity, such OFDM systems are not able to perfectly remove MAI, while FBMC suppresses MAI almost perfectly.

C. The FBMC versus OFDM Applied in Physical Layer

- Power spectral density
- Interference power at a receiver due to mutual interference across subcarriers used by different transmitters
- Magnitude performance improvement
- Packet transmission delays
- Channel access delays
- Packet Error Rate Model
- Comparison of SINR and Modulation Scheme Selection
- Comparison of Packet Error Rates

The FBMC beyond OFDM the Data Link Layer, we devise a distributed and adaptive medium access control(MAC) protocol[7] that coordinates data packet traffic among the different nodes in the network in a best-effort manner. The PPP protocol is a data link protocol for transmission on a serial link to be used OFDM Signals.

D. MAC Protocol

In the seven layer OSI model of computer networking, media access control (MAC) data communication protocol is a sub layer of the data link layer, which itself is layer 2. Cyclic prefix is often used in conjunction with modulation in order to retain sinusoids' properties in multipath channels. It is well known that sinusoidal signals are Eigen functions of linear and time-invariant systems. Addressing and channel access control mechanisms several terminals or network nodes to communicate within a multiple access network that incorporates a shared medium, e.g. Ethernet. The hardware that implements the MAC is referred to as a medium access controller

E. The FBMC Vs OFDM Applied in Data Link Layer

Transfer data from the network layer of one machine to the network layer of another machine. Convert the raw bit stream of the physical layer into groups of bits (“frames”). In any broadcast network, the stations must ensure that only one station transmits at a time on the shared communication channel. The protocol that determines who can transmit on a broadcast channel are called Medium Access Control (MAC) protocol. The MAC protocol is implemented in the MAC sub layer which is the lower sub layer of the data link layer. The higher portion of the data link layer is often called Logical Link Control (LLC).

E. PPP Protocol

PPP comes into play when you establish a connection to your ISP (Internet Service Provider) via a modem. The name PPP comes from the fact that when you are connected to our ISP, the ISP and you make up two points on the network hence the protocol that is used to get things `happening' between the two of you is the Point To Point Protocol Or The PPP.

F. Functions Of PPP

- Data Encapsulations
- Link Control
- Network Control

FBMC beyond OFDM the Network Layer, we devise a distributed and adaptive medium access control (MAC)

protocol and aggregation Algorithm Used for security purpose. This phase is optional. The MAC protocol[4] are implemented in the MAC sub layer which is the lower sub layer of the data link layer. These frames are used to accomplish the work of each of the LCP phases. Information Protocol (RIP) and Open version of Shortest Path First (OSPF), to learn of other networks that are present and to calculate the best way to reach each network based on a variety of criteria (such as the path with the fewest routers). In any broadcast network, the stations must ensure that only one station transmits at a time on the shared communication channel. This phase is optional. The MAC protocol[4] are implemented in the MAC sub layer which is the lower sub layer of the data link layer. These frames are used to accomplish the work of each of the LCP phases

G. Network Layer

The network layer must know the topology of the subnet and choose appropriate paths through it. When source and destination are in different networks, the network layer (IP) must deal with these differences.

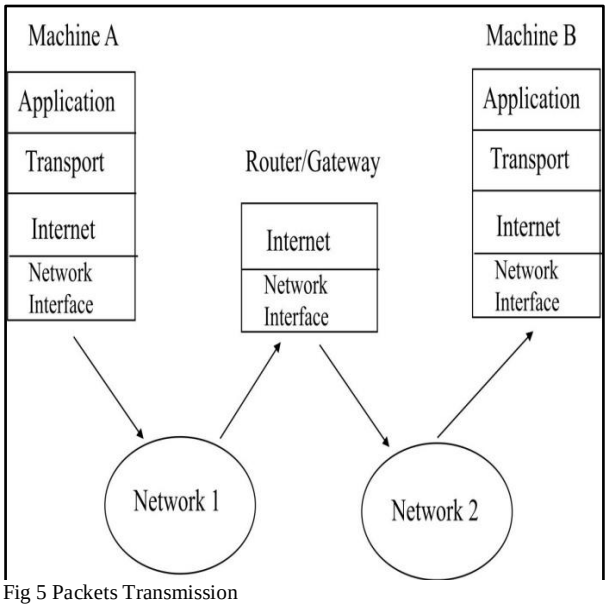

Fig 5 Packets Transmission

In Fig 5, to make it easier to manage the network and control the flow of packets, many organizations separate their network layer addressing into smaller parts known as subnets. Routers use the network or subnet portion of the IP addressing to route traffic between different networks. Each router must be configured specifically for the networks or subnets that will be connected to its interfaces. The network layer accomplishes this via a process known as fragmentation. Observe that MAI cancellation-enabled multiple-access OFDM systems are generally over an order of magnitude more complex than their FBMC counterparts. A router's network layer is usually responsible for doing the fragmentation. Routers communicate with one another using routing protocols, such as Routing. Information Protocol (RIP) and Open version of Shortest Path First (OSPF), to learn of other networks that are present and to calculate the best way to reach each network based on a variety of criteria (such as the path with the fewest routers). In any broadcast network, the stations must ensure that only one station transmits at a time on the shared communication channel.

H. Transport Layer

The transport layer accepts data from the session layer and segments the data for transport across the network. Generally, the transport layer is responsible for making sure that the data is delivered error-free and in the proper sequence. Flow control generally occurs at the transport layer. Flow control manages data transmission between devices so that the transmitting device does not send more data than the receiving device can process. Multiplexing enables data from several applications to be transmitted onto a single physical link. Virtual circuits are established, maintained, and terminated by the transport layer. Error checking involves creating various mechanisms for detecting transmission errors, while error recovery involves acting, such as requesting that data be retransmitted, to resolve any errors that occur. The transport protocols used on the Internet are TCP and UDP.

I. Session Layer

The session layer establishes, manages, and terminates communication sessions. Communication sessions consist of service requests and service responses that occur between applications located in different network devices. These requests and responses are coordinated by protocols implemented at the session layer. Some examples of session-layer implementations include Zone Information Protocol (ZIP), the AppleTalk protocol that coordinates the name binding process; and Session Control Protocol (SCP), the DECnet Phase IV session layer protocol.

VI. IMPLEMENTATION OF FBMC IN OFDM

Multiple input multiple output (MIMO) techniques are able to boost the system performance without the necessity of using additional bandwidth. The MIMO techniques are usually combined with multicarrier modulations (MCMs) to lower the dispersion of the channel. In this sense, the orthogonal frequency division multiplexing (OFDM) is the favourite MCM since the fading at the subcarrier level is modelled flat, which facilitates the implementation of the MIMO concept. However the OFDM performance relies on transmitting redundancy in the form of a cyclic prefix (CP), which has to be larger than the maximum channel excess delay.

V. BLOCK DIAGRAM

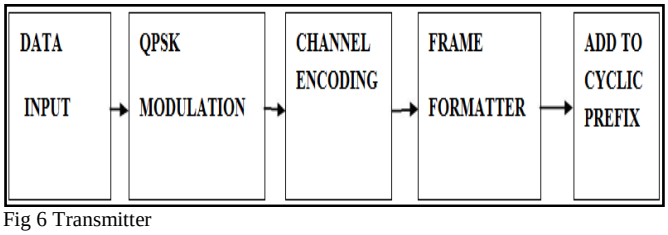

Fig 6 Transmitter

A. Data Input

It is the simplest method for generation of test data. The advantage of this is that it can be used to generate input for any type of program. Thus to generate test data we can randomly generate a bit stream and let it the represent the data type needed. However, random test data generation does not generate quality test data as it does not perform well in terms of coverage. Channel coding and which one is better based on the factor one can decide efficient channel code. The non-square constellations, dealt with below, achieve marginally better bit-error rate (BER) but are harder to modulate and demodulate. The MAC sub layer provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multiple access network that incorporates a shared medium, e.g. Ethernet

B. QPSK Modulation

QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with Gray coding to minimize the bit error rate (BER) sometimes misperceived as twice the BER of BPSK. The mathematical analysis shows that QPSK can be used either to double the data rate compared with a BPSK system while maintaining the same bandwidth of the signal, or to maintain the data-rate of BPSK but halving the bandwidth needed. In this latter case, the BER of QPSK is exactly the same as the BER of BPSK - and deciding differently is a common confusion when considering or describing QPSK. The transmitted carrier can undergo numbers of phase changes.

C. Channel Encoding

This coding is usually done to reduce the errors during the transmission of information in the channel. Usually, these codes add redundancy to the information.

D. Frame Formatter

A frame is a structural system that supports other components of a physical construction. In computer networking and telecommunication, a frame is a digital data transmission unit that includes frame synchronization, a sequence of bits or symbols making it possible for the receiver to detect the beginning and end of the packet in the stream of symbols or bits. If a receiver is connected to the system in the middle of a frame transmission, it ignores the data until it detects a new frame synchronization sequence.
In computer networking, a frame is a data packet on the Layer 2 of the OSI model. A frame is "the unit of transmission in a link layer protocol, and consists of a link-layer header followed by a packet." [2] Examples are Ethernet frames (maximum 1500 byte plus overhead), PPP frames and V.42 modem frames.

A. Cyclic Prefix

Cyclic prefix is often used in conjunction with modulation in order to retain sinusoids ' properties in multipath channels. It is well known that sinusoidal are Eigen functions of linear, and time-invariant systems. Therefore, if the channel is assumed to be linear and time invariant, then a sinusoid of infinite duration would be an eigen function. However, in practice, this cannot be achieved, as real signals are always time-limited. So, to mimic the infinite behaviour, prefixing the end of the symbol to the beginning makes the linear convolution of the channel appear as though it were circular convolution, and thus, preserve this property in the part of the symbol after the cyclic prefix. Although the receiver is typically configured to discard the cyclic prefix samples, the cyclic prefix serves two purposes.

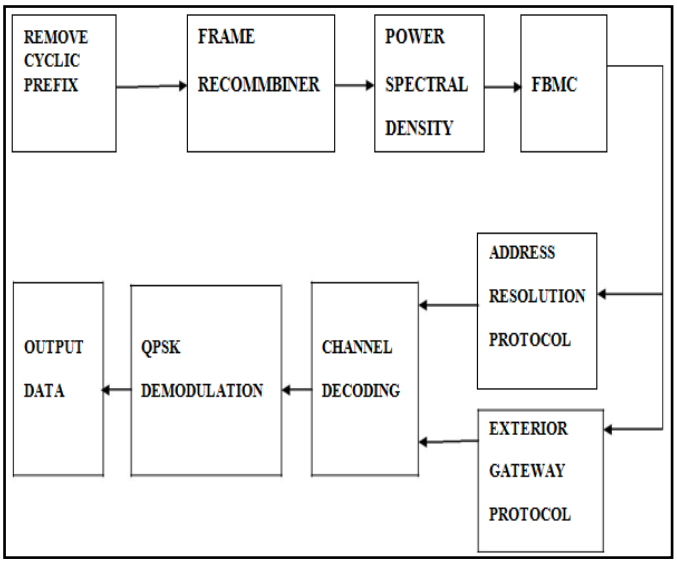

Fig 7 Receiver Block

J. Power Spectral Density (PSD)

In a normal OFDM signal, the complex values modulating the subcarriers in each symbol period are statistically independent of each other. They are also independent of the values modulating any subcarrier in any previous or subsequent symbol period. As a result the power spectrum of the overall signal can be found by summing the power spectrum of all individual subcarriers for any symbol period. The MAC sub layer[7] provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multiple access network that incorporates a shared medium, e.g. Ethernet. The hardware that implements the MAC is referred to as a medium access controller. BER is a unit less performance measure, often expressed as a percentage. Routing structures such as routing trees is well suited when there are only a few numbers of nodes in the network. Managing the routing trees in such case will become infeasible and the overlaps in the routing trees cannot be effectively utilized.

K. Address Resolution Protocol

The term address resolution refers to the process of finding an address of a computer in a network. The address is

"resolved" using a protocol in which a piece of information is sent by a client process executing on the local computer to a server process executing on a remote computer. The information received by the server allows the server to uniquely identify the network system for which the address was required and therefore to provide the required address. The address resolution procedure is completed when the client receives a response from the server containing the required address.
There are four types of arp messages that may be sent by the arp protocol. These are identified by four values in the "operation" field of an arp message. The types of message are: ARP request, ARP reply, RARP request and RARP reply

L. Exterior Routing

Internal connectivity is identified by "AS number". Routes learned from other autonomous systems Need for Exterior Routing. Need of Exterior routing is given below:

- Service Provider Selection Given Multiple Choices.
- Everything Must Scale to hundreds of thousands of Routes.
- Filtering on Networks Doesn't Scale Well.
- Separate Policy Control

VII. RESULT AND TABULATION

In this system, two nodes exchange packets using the fOFDM or FBMC physical layer. FBMC can perform very well in comparison to OFDM with high-data-rate modulation schemes. When there is a large number of nodes, computing the interference power over several subcarriers and at different points in time over each packet. Hence, to run our simulations more efficiently, whenever we compute interference power.

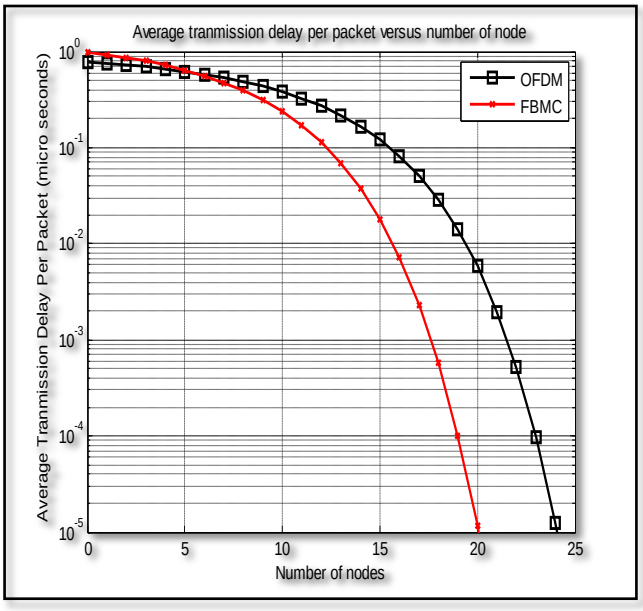

Fig 8 Average transmission delay per packet versus number of nodes

Fig 8 shows a plot of average transmission delay per packet as a function of number of nodes in the network. With 20 or more nodes, FBMC achieves an order of magnitude reduction in the average transmission delay per packet over both OFDM and fOFDM.

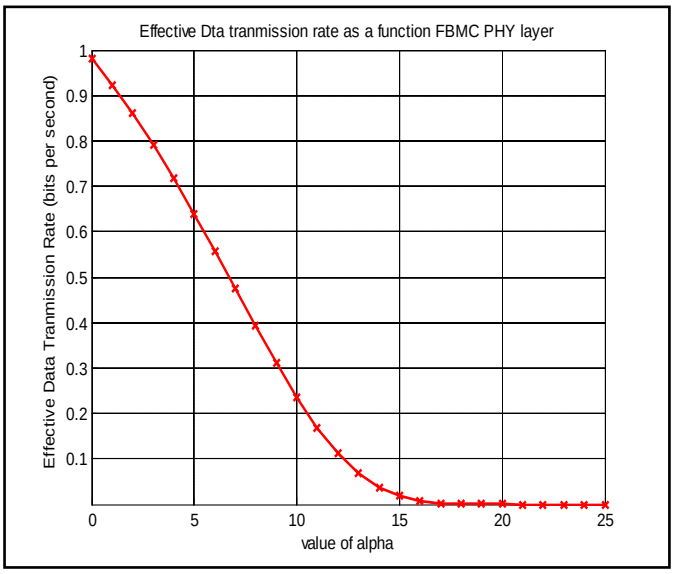

Fig 9 Effective Data Transmission rate as a function FBMC PHY layer

Fig 9 shows how the effective data transmission rate for FBMC varies with α, when β=1/α. While large (i.e., smaller) values additively increment the channel size by a large value when it is promising, multiplicative decrease due to unpromising channel causes it to shrink in size more aggressively. Furthermore, smaller values yield better performance because it increases the chance of many nodes to share the spectrum.

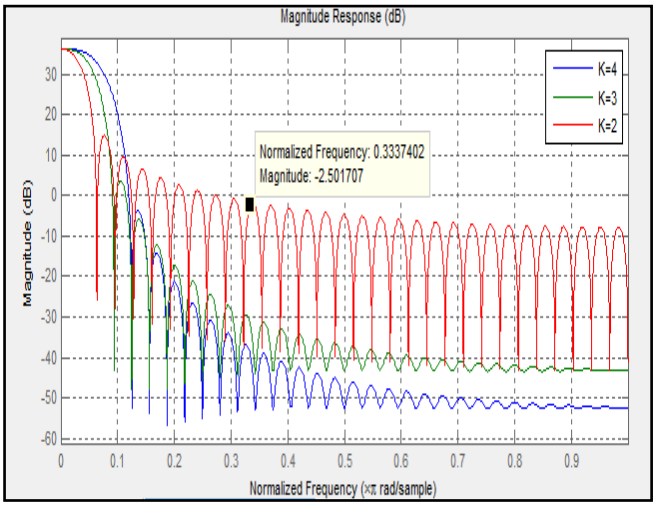

Fig 10 Magnitude response (db)

In Fig 10, the Filterbank Multicarrier is reduced the Interference and get the Distortion Less OFDM Waveform Compared to all the other Waveforms. The Red Colour OFDM Waveform has get the highest Efficiency.

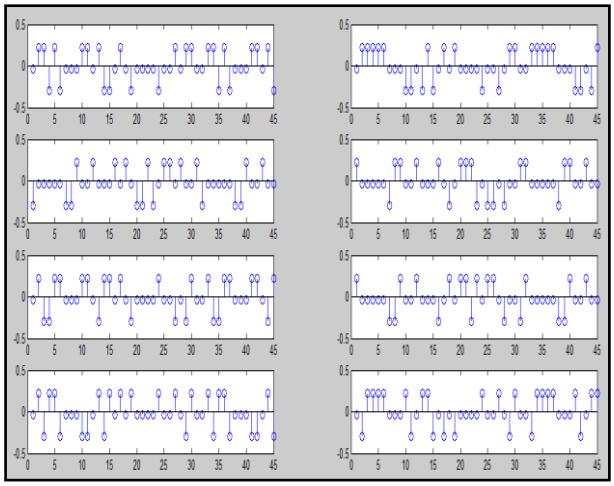

Fig 11Address Resolution Protocol

In Fig 11, based on address resolution protocol the upper values are correctly reached packets, but does not get any acknowledgement signals. In middle value packets are correctly reached and get acknowledgement signals. The lower values are does not get correct outputs.

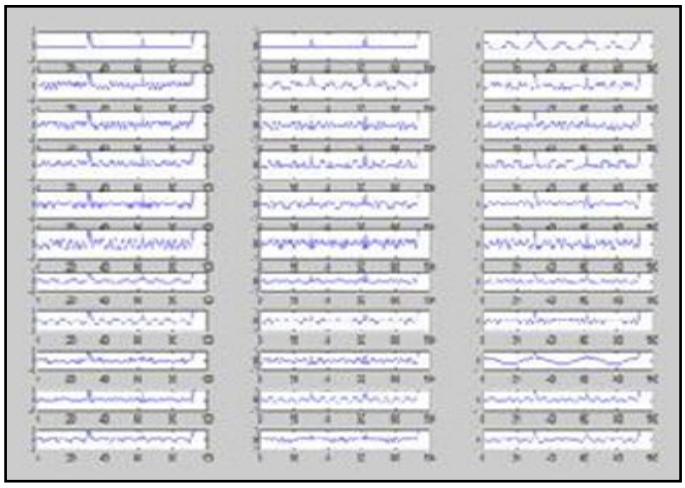

Fig 12 Transport layer

In Fig 12, Based on Transport layer all the waveforms are correctly reached from transmitter to receiver without any losses.

VIII. CONCLUSION

The use of FBMC for best-effort dynamic spectrum access networks analysed the mutual interference power across subcarriers used by different transmitters. It demonstrated the superior performance of FBMC using real-world measurements and examined the use of FBMC for dynamic spectrum access in a vehicular network setup. FBMC can achieve about smaller end-to-end packet delivery delays and relatively low packet drop probabilities in comparison to OFDM. The Transport layer, Session layer was analysed and FBMC can achieve higher SINR, very low packet error rates and noise was reduced. It achieved above 50x smaller end to end data packet delivery delays.

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