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Research Article

Received Signal Strength for Optimization of Distributed Exclusive Region Based MAC Protocol DEXRSSMAC

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Abstract:
Methods/Analysis Ultra-wideband (UWB) is the technology that can leverage broadband wireless services. UWB channels provide large bandwidth and help in supporting plethora of services and applications in cost-effective fashion. In other words, UWB can take the wireless communications and the utility of such networks to the next level. However, the existing nature of MAC protocol needs to be improved. **Findings** Therefore it is essential to have distributed, scalable and efficient MAC protocol in order to exploit UWB channels. The recent DEX based MAC protocol proposed by Cai et al. employs geometry distance to determine exclusive region in DEX protocol. They have not explored the Received Signal Strength (RSS) for the purpose. **Novelty /Improvement** In this paper we study the Received Signal Strength Indicator (RSSI) for determining the exclusive region and reserve it for users to have effective and fair sharing of resources in distributed and asynchronous manner. With our approach we quantify network performance. We implement the RSS for Optimization of Distributed Exclusive Region Based MAC Protocol (DEXRSSMAC) using NS2. Our simulations show the performance comparison of our protocol with existing ones such as EEDRP and DLBOP.

Keywords: UWB, distributed MAC protocol, distributed exclusive region, received signal strength indicator

1. Introduction

Innovations in wireless technologies rapidly changed the capacity of wireless devices in terms of bandwidth and other resources. For instance, Ultra-wideband (UWB) channels support data transmission rates in Giga bits per second (Gbps) in the transmission range up to 10 meters. Ubiquitous wireless networks with access to high data rates are possible with UWB channels in wireless networks. The process of scheduling and synchronization are costly things involved in the UWB networks. Therefore it is required to have a flexible MAC protocol that can utilize resources effectively in distributed and asynchronous fashion. Though the Distributed Coordination Function (DCF) introduced with IEEE 802.11 is successful in achieving performance, it is still inadequate to handle real time demands. There are issues in a big multi-hop networks such as unfairness and throughput starvation. Moreover DCF cannot be used directly in such networks. UWB has power adaptation issues but it supports rate adaptation with PHY layer specifications.

Cai *et al*. [1] proposed a DEX (Distributed Exclusive Region) MAC protocol for achieving the determination of regions in UWB channels that can be reserved for faire sharing of resources and effective data and acknowledge transmissions asynchronously. Inspired by the work in [1], in our previous work we proposed DUMAC [2] and EEDRP [3] in order to have blind discovery mechanism and energy efficient directional routing protocol for determining regions. In another paper of ours [4] we focused on resource allocation for multi-user multi-traffic class in UWB MANET. In this paper we explored the Received Signal Strength (RSS) which is not used by DEXMAC, DUMAC and EEDRP protocols. Received Signal Strength Indicator (RSSI) is used for determining the exclusive region and reserves it for users to have effective and fair sharing of resources in distributed and asynchronous manner. With our approach we quantify network performance. We implement the RSS for Optimization of Distributed Exclusive Region Based MAC Protocol (DEXRSSMAC) using NS2. Our simulations show the performance comparison of our protocol with existing ones such as EEDRP and DLBOP.

2. Related Work

This section reviews prior works related to this research. Bremermann (1962) [5] focused on data processing techniques and the need for quantum theory. Hajek *et al*. (1997) [6] studied largest received power and capture probability in networks with large number of stations. Gupta (2000) [7] studied the capacity of wireless networks in order to know their implications and future prospect. Deng *et al*. (2004) [8] investigated on carrier sensing range with respect to MAC to improve efficiency of IEEE 802.11 networks. Radunovic *et al*. (2004) [9] studied UWB networks with respect to routing, scheduling and optimal power control. They found that exclusive regions in UWB channels can help improve communications in wireless networks. Zhu *et al*. (2004) [10] threw light on maximizing throughput in IEEE 802.11 networks using channel clustering and physical carrier sensing. Lin and Shroff (2005) [11] studied the issues caused by imperfect scheduling in wireless networks in the context of cross layer design approaches.

Merz *et al*. (2005) [12] used a cross layer design approach by jointly optimizing PHY and MAC layers in order to improve efficiency of TH-UWB channels. Shen *et al*. (2005) [13] studied MAC layer in UWB wireless networks. The focus was on MAC over UWB with four deployment aspects. They are QoS, resource allocation, overhead reduction, and multiple accesses. Yang and Vaidya (2005) [14] studied on physical carrier sensing in ad hoc networks. Their study includes channel utilization and channel capacity without considering MAC overhead. Cardinali *et al*. (2006) [15] studied low and high data rate applications with respect to the UWB ranging accuracy. More focus was on the positioning. They analyzed the Cramer-Rao Lower Bound (CRLB) and derived it from network for finding ideal channel region. Cai *et al*. (2006) [16] investigated the capabilities of UWB networks for multimedia services. Their research reveals capacity of such networks in terms of interference, throughput, noise level, path loss exponent, and optimal cell size.

Gamal *et al*. (2006) [17] explored wireless networks using Fluid Model for finding the delay and throughput tradeoffs. Kim *et al*. (2006) [18] did their research on wireless networks in terms of data rate, carrier sense threshold, and transmit power by tuning them. They also proposed an algorithm for decentralized power control. Cai *et al*. (2007) [19] focused on MAC enhancements in UWB channels and analyzed capacity dynamics. They used different approaches and quantified the MAC enhancements that can make UWB channels more effective. Yi *et al*. (2007) [20] explored physical interference and MAC scheduling for robust networks. Wu *et al*. (2007) [21] did their research on wireless networks with greedy algorithms for efficient scheduling. They found that distributed greedy algorithms are useful in improving scheduling in wireless networks.

Sadough *et al*. (2007) [22] focused on physical layer improvement for UWB communications. They investigated multi-band OFDM with respect to PHY layer. Thus they proposed MB-OFDM approach for better performance. Cai *et al*. (2009) [23] focused on MAC protocol design for enabling UWB channels to determine regions that can be reserved for asynchronous communication between two parties over wireless network. Zhang *et al*. (2011) [24] explored characterization of various bio composites using power metallurgy method. Their research in chemical compositions led to the useful combinations that can be used in healthcare and other domains. In this paper our focus is on PHY and MAC layers to optimize determination of exclusive regions in UWB channels for enabling asynchronous communication between two parties with fair sharing of resources.

3. Preliminaries

This section provides information about Received Signal Strength Indicator and RTS/CTS as they are configured in the proposed system in order to have better way of determining region reserved for communications in UWB channels.

3.1 Received Signal Strength Indicator

In telecommunications domain RSSI is used to measure the power available with the radio signal received. This is not visible usually to the receiver device. However, RSS can vary and has its impact on the quality of communications in IEEE 802.11 networks. RSSI is used in the state known as Intermediate Frequency (IF) before amplification. With respect to IEEE 802.11 wireless standards, RSSI is measured in arbitrary units. It indicates power level in the received signal. If the RSSI is more, it means the signal strength is more. If RSSI is represented negatively 0 indicates high signal strength. RSSI can be internally used in networking card and based on a threshold it can make decisions on clear to send (CTS). Once the card indicates CTS, the packets are transmitted. End users also can view RSSI using monitoring tools like Inssider, Kismet, and Wireshart [25]. The receiver sensitivity values can be measures in either dBm or mW as shown in Table 1.

Table 1. Receiver Sensitivity dBm to mW [26]

dBm	mW
10	10
3	2
0	1
-3	0.5
-10	0.1
-20	0.01
-30	0.001
-40	0.0001
-50	0.00001
-60	0.000001
-70	0.0000001
-84	0.000000004

Interestingly IEEE 802.11 standard has not defined any relationship between power level and RSSI. The power level is measures in mW or dBm. The relationship depends on the vendors as per their devise specifications. However, RSSI sampling procedure is clear in the standard. It is sample in the preamble stage of receiving frame of 802.11 instead of getting full frame. Coarse grained location estimation was done by researchers using RSSI in the early 2000. Of late more advanced techniques are available for the same. Nevertheless, RSSI has not provided any accurate measure to know the location [25]. In this kind of research receiver sensitivity is very useful. It is defined as minimum signal power that exhibits Bit Error Rate in acceptable range. The measurement for this is either dBm or mW. The value is expressed using a negative number based on the data rate. For instance -81 dBm has lower strength then -79 dBm. As it reaches zero, its value get highest.

Table 2. Notations Used in RSRP Computations

Notations	Description
RSRP	Received Signal Received Power
RSSI	**Reference Signal Received Indicator**
RSRQ	**Reference Signal Received Quality**
P	Signal power
N	No of resource blocks across RSSI
S	Subcarriers across recourse block

RSRP (dBm) = RSSI (dBm) – 10*log (S*N)

RSRP = 10*log (P*1000)

RSRQ = 10*log(P/(S*P))

Here is an example to compute RSRP, RSSI, and RSRQ. Let us consider a resource block, 0.5 ms in time domain with 12 sub carriers. Assume that power of channels, reference symbols and others is 0.021 watt. Then the RSRP, RSSI and RSRQ are computed as follows.

RSRP = 10*log (0.021*1000) = 13.2 dBm

RSRP is nothing but linear average of downlink reference signal for any given bandwidth while the total received wide-band power is represented by RSSI.

RSSI = 10*log(0.021*1000)+10*log(12) = 24 dBm

RSRQ is now simple ratio of RSRP to RSSI with N=1

RSRQ = 10*log(0.021/(12*0.021)) = -10.79 dB

The RSSI is used to determine the exclusive region in UWB channels in order to have asynchronous communication and efficient and fair sharing of resources.

3.2 Request to Send / Clear to Send (RTS/CTS)

It is an optional mechanism available in IEEE 802.11 wireless networks employed to get rid of or reduce frame collisions. The collisions are generally introduced by a problem in wireless networks known as hidden node problem. Therefore RTS/CTS is widely used mechanism in wireless networks to reduce packet collisions and to achieve higher throughput. Sometimes they may cause inter-dependencies which leads to nodes having inability to send packets for long time. By using RTS/CTS control frames ideally it is possible to enhance communication in wireless networks. The dynamics of RTS/CTS are presented in Figure 1.

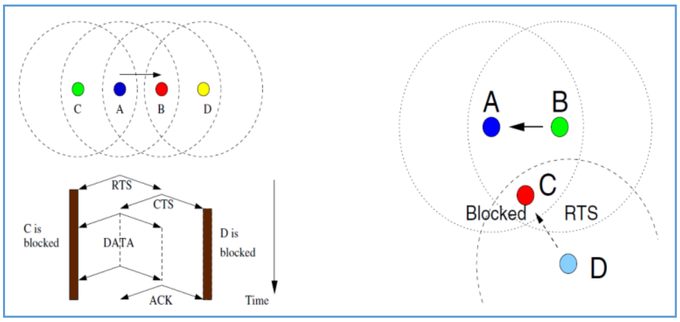

Figure 1. IEEE 802.11 MAC Usage of RTS/CTS (left) and Blocking Problem (right) [27]

Congestion is reduced when RTS/CTS mechanism is employed in wireless networks. However, there is dependency issue, it causes blocking problem where the communication between two nodes is blocked for some time. In Figure 1 (right), the node C is blocked and not able to respond to RTS packets sent by D. In this paper the RSSI and RTS/CTS are used in different layers of OSI in order to determine a region in UWB for asynchronous communication and fair sharing of resources.

4. Proposed Solution

We proposed a solution based on the layered approach of wireless communication standards. As per the OSI model there are many layers that are involved in networking applications. The application layer generally knows Quality of Service (QoS) requirements. The physical layer and MC layer are used to optimize the performance in order to determine the exclusive region for transferring data and acknowledgements and effective sharing of resources in asynchronous fashion. The overview of the proposed solution is pictorially shown in Figure 2. We implemented a protocol named Distributed EXclusive Region Based MAC Protocol (DEXRSSMAC) to achieve this. As MAC needs to be improved to achieve determination of regions, the proposed protocol uses MAC layer. However, we intend to achieve optimization of MAC layer using Received Signal Strength (RSS) associated with physical layer. Configuration of RSS in MAC layer and configuration of control signals such as CTS/RTS in MAC layer are done to achieve the desired outcome.

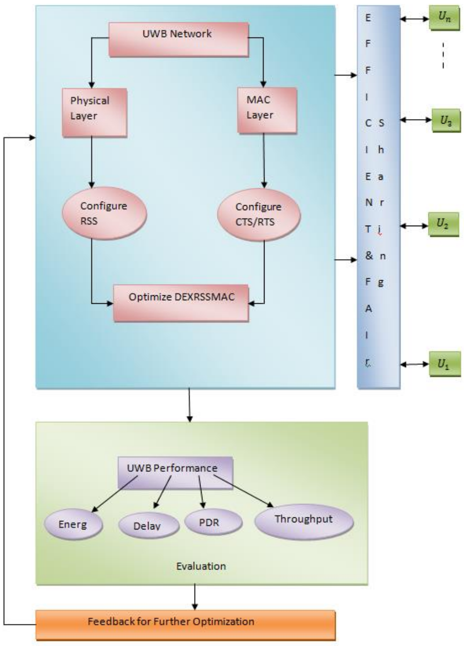

Figure 2. Overview of the Proposed Architecture

Using the proposed protocol DEXRSSMAC, the physical and MAC layers are optimized by configuring RSS and CTS/RTS and resultant functionality lies with the proposed protocol. The protocol achieves efficient and fair sharing of resources of UWB channels asynchronously. This will help users to obtain quality of services. The UWB performance is evaluated using different performance metrics such as energy consumption, delay performance, PDR, and throughput. After evaluation, the network feedback can be obtained. The reflection over the feedback can help to initiate further optimization of the protocol in future. NS2 simulation study is made in order to have the proof of concept. To achieve the best available region we configured received signal strength. The available region mostly depends on the RSS value. This is achieved by using physical layer settings.

1) rxPower 1.08918e-9 (or 150w) Phy/WirelessPhy
2) txPower 4.4613e-10 (or 100W) Phy/WirelessPhy

- ✓ rxPower represent received signal power
- ✓ txPower represent sender signal power

When a source sends the packets to destination node first check the availability of signal region it depends on the received signal strength (rxPower). Using this we can make availability signal region in the network. The sender also checks the busy tone of the receiver by sending RTS and CTS messages between source and destination.

1) CTSThreshold_ 2000 Mac/802_11
2) RTSThreshold_ 5000 Mac/802_11

Thus a cross layered approach is followed in order to determine exclusive region in a better way for effective sharing of UWB channels by improving MAC layer and physical layer. The results of the simulations are presented in the ensuing section. The performance metrics used to evaluate the results include throughput, energy consumption, delay, and packet delivery ratio.

5. 5. Simulation Results

In this paper we explored the Received Signal Strength Indicator (RSSI) for determining the exclusive region and reserve it for users to have effective and fair sharing of resources in distributed and asynchronous manner. There are many received signal strength related parameters such as free space model, two ray ground model, shadowing model, receiving power, carrier sensing threshold, CSThresh_, RxThresh_, and CPThresh_. The radio propagation used in this paper is two way ground model. The simulation environment is presented in the following sub section.

Table 3. Simulation Environment

S. No.	Parameter Type	Parameter Value
1	Channel Type	Wireless Channel
2	Radio-Propagation	Propagation/TwoRayGround
3	Network Interface	WirelessPhy
4	Interface Queue Type	DropTail
5	Antenna Model	OmniAntenna
6	Interface Queue Length	50
7	Routing Protocol	DEXRSSMAC
8	No. of Nodes	35
8	rxPower	1.08918e-9
9	txPower	4.4613e-10 (250W)
10	RXThresh	1.4613e-10 (160m)
11	CPThresh_	10
12	CSThresh_	1.559e-11
13	RXThresh_	3.652e-10
14	CTSThreshold_	2000
15	RTSThreshold_	5000

As shown in Table 3, the simulation environment used for the experiments is presented. NS2 is used for making simulations.

5.1 Performance Metrics

Performance metrics are used to evaluate the simulation results. The purpose of each metric is described here.

Table 4. Performance Metrics

Metric	**Description**
Packet Delivery Ratio (PDR)	It is the performance measure used to know the ratio between number of packets received and the number of packets sent.
Throughput	The rate of messages transferred successfully in network.
Average Delay	The time difference between packets received and packet sent.
Energy Consumption	It is the measure used to know how much energy is consumed by the network in data transmission, sensing, data processing and idle sleep state.

As shown in Table 4, four performance metrics are used to evaluate the proposed work in this paper. They are PDR, throughput, average delay and energy consumption.

Tab1e 5. Delay Performance Comparison

	Delay Performance		
	DEXRSSMAC	**EEDRP**	**DLBOP**
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0.113162749	0.123162749	0.1431627
9	0.063668357	0.083668357	0.01036684
10	0.047201191	0.049201191	0.0692012
11	0.03899064	0.05899064	0.0889906
12	0.034037057	0.054037057	0.0840371
13	0.030746405	0.050746405	0.0607464
14	0.028409411	0.048409411	0.0684094
15	0.026632375	0.046632375	0.0666324
16	0.025259064	0.045259064	0.0652591
17	0.024174817	0.044174817	0.0641748
18	0.023264792	0.043264792	0.0463265
19	0.022516821	0.042516821	0.0625168
20	0.022516821	0.042516821	0.0625168

As shown in Table 5, it is evident that the delay performance of the proposed protocol **DEXRSSMAC** is compared with that of EEDRP and DLBOP. The delay is decreased as the simulation time is increased. DLBOP has shown better performance when compared with EEDRP. The proposed protocol outperforms both DLBOP and EEDRP protocols. When simulation time is 20 seconds, the proposed protocol shows 0.022516821, EEDRP 0.042516821, and DLBOP 0.0625168 delay performance respectively.

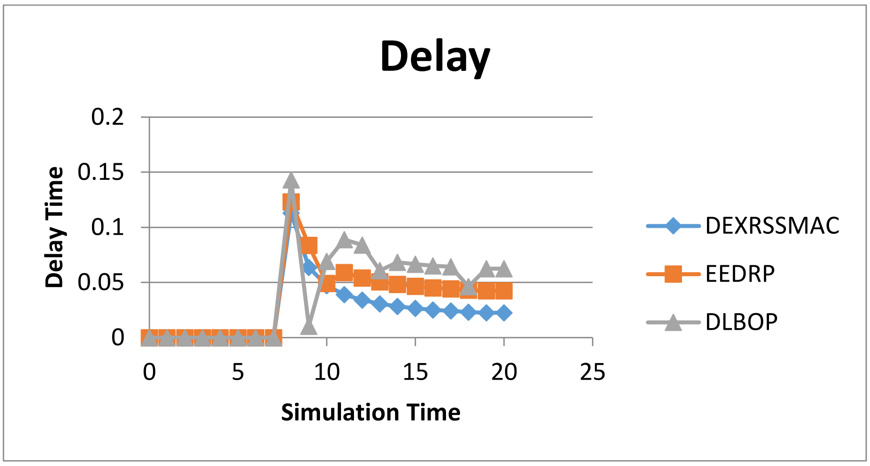

Figure 3: Delay Performance Comparison

Delay performance of the proposed protocol DEXRSSMAC is compared with that of EEDRP and DLBOP. As simulation time increases, the delay time is decreased. This trend is true with all the protocols compared. Apart from this trend, the DLBOP provides relatively less performance when compared with that of EEDRP. The proposed protocol performs better than the other two protocols. The rationale behind this is the optimization made in MAC in the proposed protocol for determining exclusive regions.

Table 6. Energy Consumption

	Energy Consumption (joules)		
Simulation Time	**DLBOP**	**EEDRP**	**DEXRSSMAC**
0	90	90	90
1	75.2	85.2	85.2
2	73.3	83.3	83.2
3	70.4	80.4	80.4
4	66.42	78.42	76.42
5	57.51	77.51	77.51
6	45.53	65.53	75.53
7	40.51	60.51	70.51
8	35.55	55.55	65.55
9	35.5	55.5	65.5
10	35.42	55.42	65.42
11	35.41	55.41	65.41
12	26.4	46.4	56.4
13	22.42	42.42	52.42
14	21.41	41.41	51.41
15	20.42	30.42	45.42
16	20.48	30.48	43.48
17	20.38	30.38	45.38
18	20.32	30.32	40.32
19	20.21	30.21	40.21
20	20.11	30.11	40.11

Energy consumption is another performance metric employed in this paper for comparing different protocols. The simulation time is considered from 0 seconds to 20 seconds incrementing by 1 gradually. As the results revealed when the simulation time is increased the residual energy is reduced gradually. The energy value recorded for all protocols when simulation time is 90. Provided this fact, the trends in energy consumption are presented with the results as simulation time increases. When simulation time is 20, the residual energy of proposed protocol DEXRSSMAC is 20.11. In the same fashion EEDRP has 30.11 and DLBOP has 40.11 joules as residual energy. These insights provide useful information about the performance of the protocols with respect to energy efficiency.

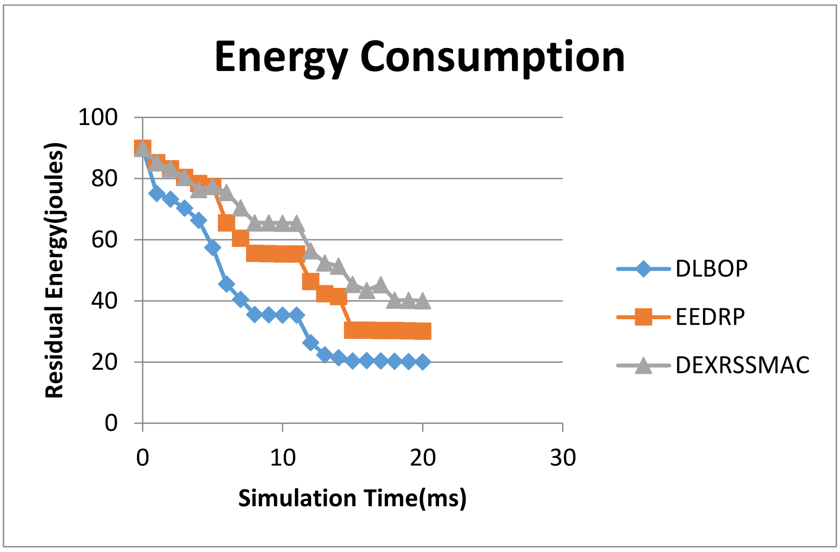

Figure 4. Energy Consumption

As shown in Figure 4, it is evident that the simulation time and energy consumption trends are shown in horizontal and vertical axes respectively. As the simulation time increases, the residual energy is decreased for all protocols studied. However, the energy efficiency of the proposed protocol DEXRSSMAC is more than the other two protocols EEDRP and DLBOP.

Table 7. Packet Delivery Ratio

Simulation Time	Packet Delivery Ratio		
	DEXRSSMAC	EEDRP	DLBOP
0	17	15	10
1	18	16	11
2	19	15	14
3	18	19	12
4	19	22	15
5	20	25	18
6	21	24	18
7	22	23	17
8	25	22	19
9	27	24	19
10	22	20	20
11	23	21	19
12	23	22	18
13	24	23	19
14	22	24	21
15	25	25	20
16	22	19	16
17	25	21	15
18	27	23	14
19	30	27	15
20	30	27	15

As far as packet delivery ratio is concerned, the proposed protocol DEXRSSMAC shows better performance when compared with the other two protocols called EEDRP and DLBOP. DLBOP exhibits poor PDR when compared with the EEDRP protocol. In the same fashion, EEDRP shows inferior performance to the proposed protocol. PDR is increased when simulation time is increased. This is true for all protocols studied in this paper.

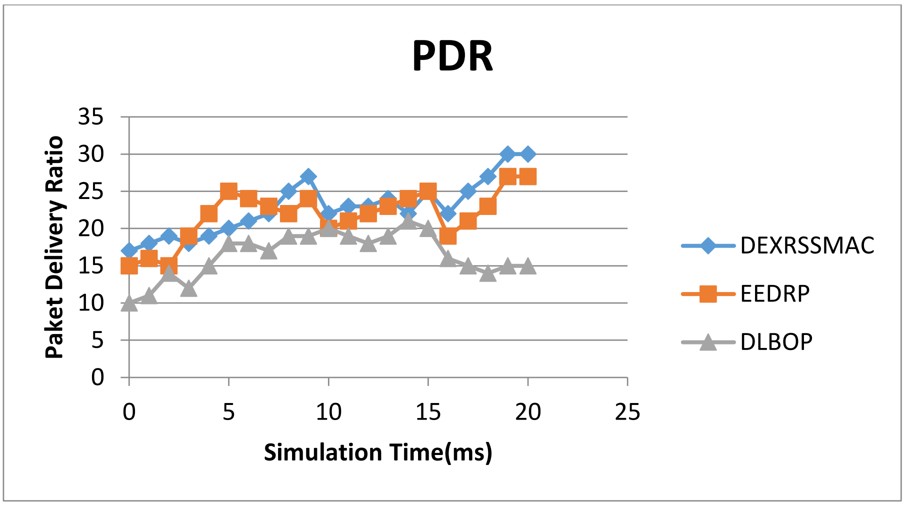

Figure 5. Packet Delivery Ratio

As shown in Figure 5, it is evident that the packet delivery ratio of the proposed system is almost better than EEDRP throughput simulation time except in the initial period and when the simulation time is between 3 and 6 seconds. EEDRP shows superior performance over DLBOP. When the proposed protocol is compared with EEDRP, it shows slightly improved performance.

Table 8. Throughput Performance Comparison

Simulation Time	Throughput		
	DEXRSSMAC	**EEDRP**	**DLBOP**
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	42560	12560	2560
9	42560	15560	5560
10	42560	17560	7560
11	42560	19560	9560
12	42560	21560	11560
13	42560	22560	12560
14	42560	23560	13560
15	42560	25560	15560
16	42560	27560	17560
17	42560	29560	19560
18	42560	31560	21560
19	42560	35560	25560
20	42560	35560	25560

The throughput performance comparison is made in Table 8. The results revealed the number of bytes transmitted by different protocols as simulation time increases. The throughput of the three protocols such as DEXRSSMAC, EEDRP and DLBOP is 42560, 12560 and 2560 bytes respectively. This observation is when simulation is at 8 seconds. When simulation time is 20 seconds, the throughput performance of aforementioned protocols is 42560, 35560, and 255560 respectively. The proposed protocol outperforms the remaining two protocols. However, EEDRP shows better throughput performance when compared with that of DLBOP.

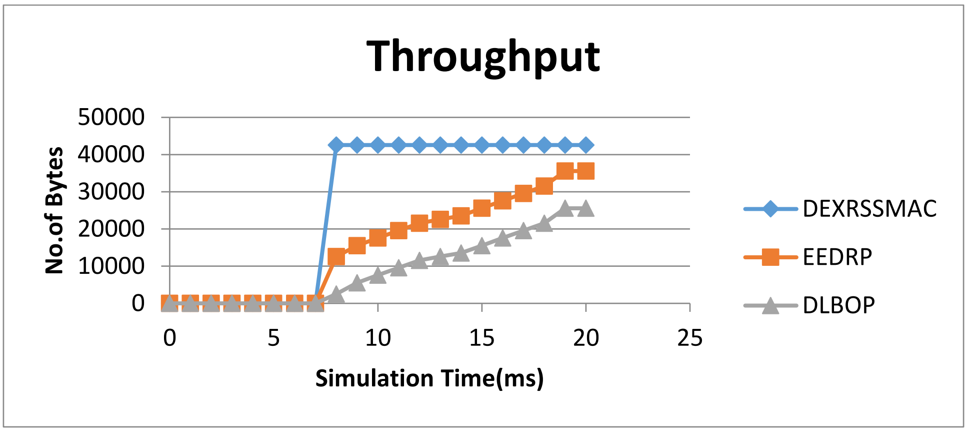

Figure 6. Throughput

As shown in Figure 6, it is evident that high throughput rate is achieved by DEXRSSMAC when simulation time is at 7 seconds approximately. Then for the rest of simulation time, the proposed scheme shows significant improvement over other protocols. Once the simulation time cross 7 seconds, the proposed protocol shows consistent performance throughout the rest of the simulation time. The simulation time considered for empirical study is 0 to 25 seconds incremented by 5 seconds.

6. Conclusions And Future Work

Broadband wireless services with the radio technology Ultra-wideband are promising to provide high bandwidth communications over radio spectrum. Besides providing large bandwidth UWB channels support other applications for cheaper price. Next level of wireless communication networks with high utility is possible with the usage of UWB. However, the nature of MAC protocol needs to be optimized in order to have more effective UWB channels. There is need for MAC protocol which can exploit UWB channels besides being scalable and distributed in nature. The recent work produced by Cai *et al*. proposed DEX protocol which is based on MAC to determine exclusive region using geometry distance so as to support fair and efficient sharing of resources in UWB network. However, they did not explore Received Signal Strength (RSS) for the same purpose. In this paper we study the Received Signal Strength Indicator (RSSI) for determining the exclusive region and reserve it for users to have effective and fair sharing of resources in distributed and asynchronous manner. With our approach we quantify network performance. We implement the RSS for Optimization of Distributed EXclusive Region Based MAC Protocol (DEXRSSMAC) using NS2. Our simulations show the performance comparison of our protocol with existing ones such as EEDRP and DLBOP. This research can be extended further by considering fast fading and shadowing while determining exclusive regions.

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