International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V70I9P215

Volume 70 Issue 9, 148-154, September 2022
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Original Article

Network throughput Optimization for Relay Based NB-CR-IoT Wireless Body Area Network

Srinivasa Rao Patri[1], L. Nithyanandan[2]

[1] *ECE Department, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, India.*
[2] *ECE Department, Puducherry Technological University, Puducherry, India*

[1]*Corresponding Author : srinivasarao.patri@gmail.com*

Received: 08 June 2022 Revised: 05 September 2022 Accepted: 11 September 2022 Published: 17 September 2022

Abstract *- In day-to-day life, technology plays a significant role in modern evolution. The rise of technology has created new requirements for networks designed to handle the increasing number of smart devices. These new requirements require the adaptation of existing technologies to new realities. The rise of technology has created new requirements for networks designed to handle the increasing number of smart devices. These new requirements require the adaptation of existing technologies to new realities. These are the destiny of modern-day healthcare structures; with each clinical tool related to the internet and monitored by scientific experts' fitness care will be provided quicker and at a decreased price. As the era progresses, patient vitals are received through sensor gadgets and sent through the internet to IoT packages. For example, of IoTs, the information is forwarded to healthcare specialists and medical professionals who respond to folks who require aid. IoT envelops a wide assortment of remote advances across an exhibit of medical care applications and is expected to grow further, assuming the quantity of IoT gadgets increments network traffic additionally increments as this multitude of gadgets need admittance to the channel that causes network congestion notwithstanding this inquiry there is one more issue where a more prominent number of IoT gadgets need a more noteworthy number of organization assets for example transfer speed transmission power and equipment gear with these disadvantages the organizations throughput is exceptionally low. To overcome the above limitations and to identify the vacant channels in the network, spectrum sensing needs to be done. Spectrum sensing refers to using an energy detector to identify the energy of a channel. It is important to optimize the throughput of the NB-IoT network because IoT devices do not have hardware facilities to perform spectrum sensing techniques for longer durations; This research provides a set of optimal collaborative sensing parameters for a Narrowband Cognitive Radio IoT (NB-CR-IoT) network that maximizes throughput. In this context, the principle of network relay for the NB-CR-IoT Network is proposed in this paper to improve network throughput*.

Keywords *- Cognitive Radio (CR), Narrow-Band Internet of Things (NB-IoT), Relay, Spectrum Sensing, Throughput Optimization.*

1. Introduction

There is an outrageous ascent sought after for brilliant things in day-to-day existence with the coming of innovation. The Internet of Things (IoT) is one of the key parts that empowers us to associate with IoT gadgets. For various enterprises and areas, like designing, medical care, public foundation the board, broadcast communications, and numerous others [1], IoT creates a wide variety of business opportunities. Wireless sensor Network (WSN) has been viewed as having different applications in medical services, travel, retail, diversion, industry, subordinate consideration, crisis the board and more. With the Internet and cell phone, innovation has given a foundation and stage for another inventive clinical application open to a greater part of the population. Medical care suppliers around the globe realize it is basic for patients; wellbeing data is precise, available, and caught in real-time. There is a high demand for interoperable smart devices in healthcare systems to drive data accuracy and workflow efficiencies. These requirements led to increased wireless devices and increased wearing of wireless sensor devices by patients for monitoring their health conditions, narrow band internet of medical things. there are several applications and everyday issues where WBAN gives its fundamental job and quality to human existence. Likewise, direct a server of various gadgets currently accessible to fabricate WBAN. The ECG (12 leads) has a data rate of 288 kbps with 100-1000 Hz bandwidth where an ECG, up to 12 sensors (cathodes) are appended to the chest. The cathodes are tacky patches with wires that interface with a screen. They record the electrical signs that make the heartbeat. The EMG has a data rate of 320 kbps with 0-10,000 Hz bandwidth; the function of this sensor is to permit the client to quantify the electrical action of muscles. It very well may be utilized as a control signal for prosthetic gadgets. The EEG has a data rate of 43.2 kbps with 0-150 Hz bandwidth. The Blood saturation sensor has16 a bps data rate of 0-1 Hz bandwidth where the function of A heartbeat oximeter harmlessly gauges the oxygen immersion of a patient's blood. This gadget comprises a red and an infrared light source, photograph identifiers, and a test to communicate light through a clear, throbbing blood vessel bed, a fingertip or ear cartilage. Glucose monitoring has a 1600 bps data rate and 0-50 Hz bandwidth. The Temperature sensor has a 120 bps data rate and 0-1 Hz bandwidth. NB-IoT is unconfined by third generation partnership project 3GPP; a significant part of IoT is the arising, and supportable 5G radio access innovation that can uphold the enormous number of gadgets with low power qualities, extensive battery duration, more coverage area, and wide scope support advances like wi-fi ZigBee, Bluetooth and 2G3G4G does not meet the requirements of IoT [21]. Cooperative communications have received much attention as an evolving transmission approach for wireless networks [15,16]. The problem for the multihop transmission using the relays for the wireless networks is studied by I. Maric et al. [17]. The fundamental concept is that the relay nodes can behave as a virtual antenna array to abet the source node in forwarding its information to the destination. The new use of the antenna as the relay source used in cooperative networks is proposed by J.Luo et al. [19], where using the relay gives the maximum throughput and better efficiency for the entire channel. Cooperative communication thus takes advantage of the wireless network's broadcasting nature. Cooperative communication efficiency relies on vigilant allocation of resources such as relay placement, relay selection and power control. More bandwidth is required as the number of IoT devices grows since all IoT devices need spectrum access to transmit data. Each system can try to reach the spectrum anytime with its small data packets. It causes congestion in the network as the bandwidth is small. Two major requirements for machine-to-machine communication are power and bandwidth to ensure reliable connectivity between IoT devices [2]. Coupling cognitive radio with random access strategies allows us to decrease network congestion [3]. 3GPP (Third Generation Partnership Project), a newly launched cellular network belonging to the 5G family of networks, has released a Narrowband Internet of Things (NB-IoT) to fulfil the above requirements and improve network throughput. It is a wide-area technology with low power specifically designed for IoT applications. This technology provides attractive choices for IoT because of its energy efficiency and ability to transmit large packets over long distances. Direct data transmission of CENUs consumes the battery life of NUs; in some IoT applications, NU's battery life is 10 years. To increase the battery life of NU, relay-based data transmission is proposed; in this paper, to increase the energy efficiency of the NB-IoT network, a three-hop data transmission from cell edge NU to eNB is proposed by using the double auction method. Capacity and Energy Efficiency are very important in the system. The relay path is proposed for better efficiency [21]. Compared with two hops, a three-hop data transmission increases the battery life of NUs NB-IoT can co-exist with older 3G and 4G networks, allowing a wide variety of devices to be served by communications within existing GSM and LTE networks, making it more cost-effective for IoT connectivity. NB-IoT also serves as a licensed spectrum network, ensuring strong interference security and independence, improving its effectiveness. For multi-user cooperative communication, the forward allocation problem is solved by J.Luo et. S. [18]. The alternative of relay selection and power allocation for a decoder and forward (DF) cooperative network depended on the pricing of energy which Feng Ke et al. Al expressed.[19].NB-IoT derives many advantages from LTE [4] (long-term evolution); guard-band mode, in-band mode and standalone modes are the available NB IoT channel deployment modes. Rather than utilizing the empty channels, a devoted divert is expected in the above modes to impart between NB-IoT gadgets, resulting in inefficient use of the available spectrum. However, we need to define the vacant channels and assign these channels for communication between NB-IoT devices to use the spectrum efficiently. Spectrum sensing plays a major role in Cognitive Radio Networks. Vacant channels in the spectrum need to be identified using spectrum sensing techniques. Vacant channels are those channels which the primary user does not use.

2. System Model

Primary users (PUs) and secondary users (SUs) are the two types of users in a Narrow Band Cognitive Radio Internet of Things system (SUs). PUs (narrowband-IoT devices (NUs)) are used for person-to-person communication, and SUs (narrowband-IoT devices (NUs)) are used for device-to-device communication. Discharge needs to utilize all range assets. NUs can utilize those assets without PUs. NU should perform range detecting to decide if the PU is communicating or not. Range detecting is finished by considering the proportion of sign to clamor as a component. A remote Aloha network convention is utilized in this collaborative sensing technique.

For its operation, the NB-CR-IoT network uses the slotted ALOHA protocol. An extension of pure ALOHA is Slotted ALOHA [5]. In the next time slot, the ALOHA protocol is used primarily to determine which station can transmit its data. The distinctive characteristics of pure ALOHA and Slotted ALOHA protocols are that each station can transmit any instance of time in pure ALOHA, so there can be a probability of data packet collision. If the received signal is acknowledged, it is very safe to send the following signal, or if the two signals clash (Overlap), they will be impaired. The stations look forward to a random period when a signal is disrupted and re-transmit the frame before it is effectively transmitted [6]. Although each station will transmit in a single time slot in the Slotted ALOHA protocol, a collision of data packets is avoided. In Pure ALOHA, there is no need to consume the group assets continuously, and a control channel is no longer required. Therefore, it becomes a very simple circuit with less hardware with the abovementioned features. Here the above definition of slotted ALOHA is applied, i.e., the whole-time resource is split into some time slots, each allocated to a CR-IoT device. The data can only be sent at the beginning of each time slot. Here, by combining the slotted ALOHA and NB-CR-IoT networks in a single two-stage slot, the CR-IoT system can sense the spectrum in the first stage and determine whether to transmit its data packet based on the sensing details.

2.1. Spectrum Sensing

The first stage in the operation of Cognitive Radio is spectrum sensing [7]. By comparing the threshold value with the detected energy of the channel, the PU signal presence is detected by the CR-IoT devices. If the observed value is greater than the threshold value, the presence of a PU signal or PU signal is involved in the transmission. Otherwise, the PU would be idle [22]. In the literature, more than a few detection methods have been recommended to improve the precision of detection. Detection of active primary transceivers in the vicinity of cognitive radios is the most powerful way to sense spectral opportunities [9]. It is efficient to use simple signal processing procedures aimed at IoT systems with many advantages, such as less power consumption and low system cost. Therefore, as the spectrum sensing method, simple non-coherent energy detection is chosen [10]. The purpose of a spectrum sensing device is to decide if a particular channel occupies the PU or whether it is free to use. The sensing principle is to decide between two H_0 and H_1 hypotheses [23]. Where H_0 represent the absence of a PU signal and H_1 represents the presence of a PU signal, respectively.

$$R(x) = \begin{cases} n(x), & H0 \\ s(x) + n(x), & H1 \end{cases} \qquad \dots(1)$$

Here, n(x) is assumed to be a noise distributed by the zero means and known variance (σx^2), which is a complex Gaussian. By the zero mean and known variance (σs^2), the received signal is interpreted as s(x) on the CR-IoMT device. The goal is to evaluate the NB-IoT system's throughput under a low signal-to-noise ratio. Therefore, devices with the same packet transmission priority and SNR detection at the same frequency [12] are considered.

$$\gamma = \frac{\sigma s^2}{\sigma x^2} \qquad \dots(2)$$

Here, the energy detector described above collects independent samples of Ks. The Energy detector collects all the sample energy, which is added at the access point. The access point takes the decision based on the samples of energy collected. The energy detector output decision is as follows

$$E(R) = \sum_{x=1}^{Ks} |R(x)|^2 \qquad \dots(3)$$

Let the selected threshold at the access point be γ, then the probability of false alarm P_{fa}= P(H1|H0) and the probability of detection P_d= P(H1|H1) as follows.

$$P_{fa} = p(E(R) > p|H0) = Q\left(\frac{Y - K_s\sigma_x^2}{\sqrt{K_s}\sigma_x^2}\right) \qquad \dots(4)$$

$$P_d = p(E(R) > p|H1) = Q\left(\frac{Y - K_s\sigma_x^2(\gamma + 1)}{\sqrt{K_s}\sigma_x^2(\gamma + 1)}\right) \qquad \dots(5)$$

a well-known expression (6) is used to find the number of samples that can be required for energy detection as

$$K_s\left(P_{fa}, P_d\right) = \gamma^{-2}\left[Q^{-1}\left(P_{fa}\right) - (\gamma + 1)Q^{-1}(P_d)\right]^2 \qquad \dots(6)$$

2.2. Collaborative Sensing

This study considers a slotted ALOHA network and concludes that spectrum sensing is repeated at regular intervals. All NB-CR-IoT devices sense the spectrum simultaneously and remain inactive during the sensing slot, implying more coordination between the devices. However, by using sensing cycles, this method can limit self-interference amongst NB-CR-IoT devices. Implementation characteristics of collaborative sensing [12] mechanism are independently implemented to determine the optimal throughput that can be achieved with each sensing mechanism and to give a basic trade-off between each sensing mechanism. One time slot is available on each NB-CR-IoT device. Each NB-CR-IoT device is also assigned a distinct time slot. To detect the PU signal in the network, all CR-IoT devices execute spectrum sensing for Ts seconds. All CR-IoT devices will detect the spectrum via collaborative sensing, and this information will be relayed to the central node. Here the central node makes the final decision about the presence of PUs signal, which is conveyed to all CR-IoT devices in the network [13,14]. A collaborative sensing system aimed at sensing, communicating the sensing information to the central NU, and communicating central NU decisions to all other NB-CR-IoT devices, it reserves Ts and Tcs seconds. Frame structures and the network model for collaborative sensing are shown in Figs.

Collaborative sensing takes centralized decisions and provides more accurate results, especially under low SNR scenarios. A dedicated channel is required to transmit the sensing information to the central NU and receive the centralized decision from the central node.

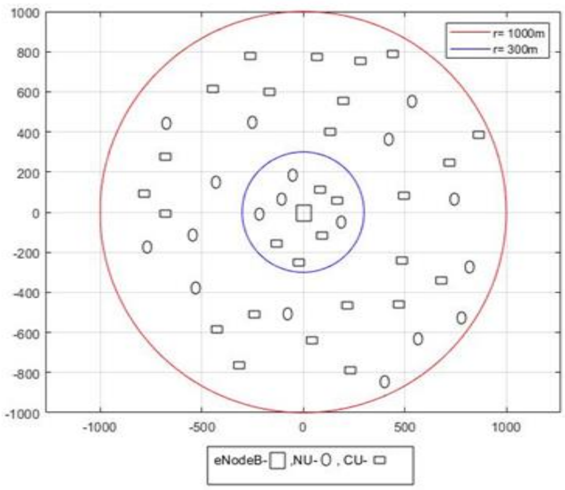

Fig. 1 NB-CR-IoT network model for collaborative sensing

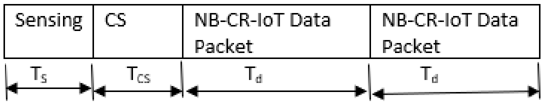

Fig. 2 The frame structure of NB-CR-IoT relay-based devices.

In the collaborative sensing network, when the central node makes a wrong decision as the absence of PU though the PU is present, then it creates interference in the network. Let us assume that S active NB-CR-IoT devices are present; all these devices conduct spectrum sensing at a time, so we apply OR activity to combine the decisions of all these devices in the central node.

3. Throughput Optimization for NB-CR-IoT Network

In this session, a relay-based NB-CR-IoT network's network throughput is calculated using the time utility function and network throughput of a slotted ALOHA protocol [12]. The time utility of collaborative sensing depends on data transmission time, sensing time and collaborative sensing time. Whenever NU data is transmitted in the proposed relay-based model to the SU, time utility depends on NU data transmitted to the SU and SU data transmitted to the eNB.

3.1. Time Utility of Collaborative Sensing without using relay

The NB-CR-IoT network communication bandwidth is assumed to be W. Then, in collaborative sensing in NB-CR-IoT network without the use of relay[12], we define the total number of devices as K = WT, the total number of sensing devices is Ks = WTs, the total number of collaborative sensing devices is Kcs = WTcs, the total number of data transmission devices is Kd = WTd, and the time slot T = Ts + Tcs + Td. The time utility of collaborative sensing is defined as the ratio of a data packet's time duration to the time duration of an entire time slot. A relay principle is used in collaborative sensing to reduce the transmitting power required by the NB-IoT cell edge unit. In region r_1, NU data will be transmitted to the CU in region r_2, in which the CU serves as a relay for transmitting NU data to the eNB. The time utility of collaborative sensing [9] is defined as

$$\mu_{Cr1}(P_{fa}, P_d) = \frac{\mathrm{T_d}}{\mathrm{T_s} + \mathrm{T_{cs}} + \mathrm{T_d}} \qquad \ldots (7)$$

$$\mu_{Cr1}(P_{fa}, P_d) = \frac{\mathrm{T} - \mathrm{T_s} + \mathrm{T_{cs}}}{\mathrm{T}} \qquad \ldots (8)$$

$$\mu_{Cr1}(P_{fa}, P_d) = \frac{\mathrm{K} - \mathrm{K_{cs}}}{\mathrm{K}} - \frac{\mathrm{K_s}(P_{fa}, P_d)}{\mathrm{K}} \qquad \ldots (9)$$

$$\mu_{Cr1}(P_{fa}, P_d) = \frac{\mathrm{K} - \mathrm{K_{cs}}}{\mathrm{K}} - \frac{\gamma^{-2}\left[Q^{-1}(P_{fa}) - (\gamma+1)Q^{-1}(P_d)\right]^2}{\mathrm{K}} \qquad \ldots (10)$$

3.2. Time Utility of Collaborative Sensing using relay

NB-IoT devices are secondary users; NUs in region r1 are required to sense the spectrum, and sensing information is sent to the access point, but when Nu's data is sent to the cellular users (CUs) which are in region r_2 is not required to sense the spectrum because of CUs can use licensed spectrum. Whenever data is transmitted from CU to eNB in region r2, the total time is utilized to transmit the data only, so the time utility in region r_2 is considered 1. The time utility of collaborative sensing using a relay is defined in region r_1 as

$$\mu_{Cr2}(P_{fa}, P_d) = 1 \qquad \ldots (11)$$

The total time utility using a relay is

$$\mu_{Cr}(P_{fa}, P_d) = \mu_{Cr1}(P_{fa}, P_d) + \mu_{Cr2}(P_{fa}, P_d) \qquad \ldots (12)$$

$$\mu_{Cr}(P_{fa}, P_d) = \frac{\mathrm{K} - \mathrm{K_{cs}}}{\mathrm{K}} - \frac{\mathrm{K_s}(P_{fa}, P_d)}{\mathrm{K}} + 1 \qquad \ldots (13)$$

$$\mu_{Cr}(P_{fa}, P_d) = \frac{2\mathrm{K} - \mathrm{K_{cs}}}{\mathrm{K}} - \frac{\mathrm{K_s}(P_{fa}, P_d)}{\mathrm{K}} \qquad \ldots (14)$$

$$\mu_{Cr}(P_{fa}, P_d) = \frac{2\mathrm{K} - \mathrm{K_{cs}}}{\mathrm{K}} - \frac{\gamma^{-2}\left[Q^{-1}(P_{fa}) - (\gamma+1)Q^{-1}(P_d)\right]^2}{\mathrm{K}} \qquad \ldots (15)$$

The network throughput of an NB-CR-IoMT network is

$$\eta_{Cr}(P_{fa}, P_d) = \mu_{Cr}(P_{fa}, P_d)\eta_0(P_{fa}, P_d) \ldots (16)$$

Where $\eta_0(P_{fa}, P_d)$ is the network throughput of a slotted ALOHA protocol

$$\eta_0(P_{fa}, P_d) = (1 - P_{fa})Me^{-(P_{fa})}e^{-(1-P_{fa})Me^{-(P_{fa})M}} \quad \ldots(17)$$

Network throughput of the proposed relay-based NB-CR-IoMT network is

$$\eta_C(P_{fa}, P_d) = \left(\frac{\mathrm{K}-\mathrm{K}_{\mathrm{cs}}}{\mathrm{K}} - \frac{\gamma^{-2}\left[Q^{-1}(P_{fa})-(\gamma+1)Q^{-1}(P_d)\right]^2}{\mathrm{K}}\right)x(1 - P_{fa})Me^{-(P_{fa})}e^{-(1-P_{fa})Me^{-(P_{fa})M}} \quad \ldots(18)$$

4. Simulation

This section simulates the relay-based NB-CR-IoT network for wireless body area networks using collaborative sensing. The simulation parameters are consistent with the 3GPP NB-IoT network standards for each 15KHz NU device bandwidth in a 180KHz resource block. Fig. 3 indicates that the network throughput of the slotted ALOHA protocol for the number of active devices(M) is 6. The network output of the slotted ALOHA system is compared to the likelihood of false alarms at 0.05 and 0.1 Because only a few devices transmit data. There is less interference, and network throughput will be high if the number of active devices is limited. As the number of active devices grows, so does the amount of interference, resulting in a decrease in network throughput Fig.4 shows the network throughput for the number of active devices 4 and 20 of the slotted aloha protocol. Network throughput will be reduced as the number of active devices increases, but network throughput will be measured for various pfa values. For the NB-CR-IoT network, this slotted aloha network throughput protocol is implemented.

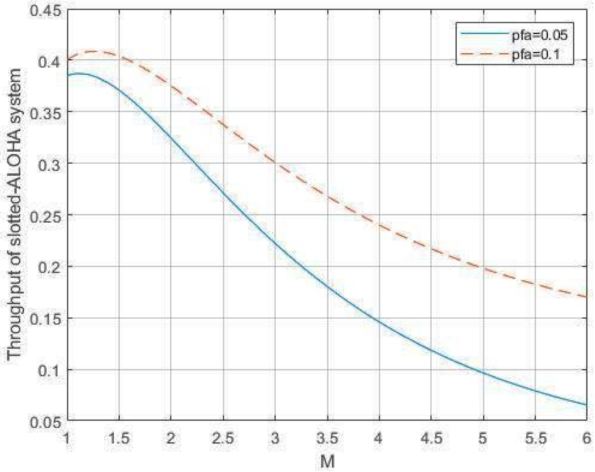

Fig. 3 Throughput of Slotted-ALOHA system vs M

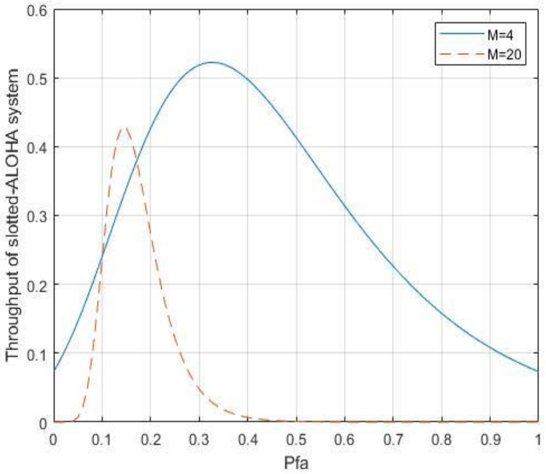

Fig. 4 Throughput of Slotted-ALOHA system vs Pfa

Fig. 5 shows the throughput of the relay-based NB-CR-IoT wireless body area network using collaborative sensing with K=1800, Kcs=100, Ns=50 and M=4. In this proposed relay-based NB-CR-IoT network, throughput is enhanced. The Narrow Band IoT device selects relays in the relay-based NB-CR-IoT network. Network throughput will increase when the distance between NU and CU is less. CUs transmit the NU data, and spectrum sensing is not needed for CUs as CUs use licensed spectrum, and the total time will be used to transmit the data. If the probability of a false alarm is large, the signal will be detected as noise, affecting network throughput. The NB-CR-IoT network will be boosted because of this. In Fig 6, the proposed method is based on relays. Because the relay distance to the NU is low, network throughput is boosted when compared to when there is no relay.

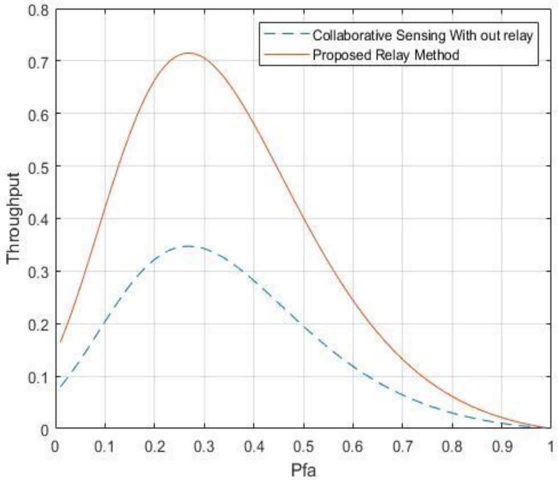

Fig. 5 Throughput of NB-CR-IoT network vs P_{fa}

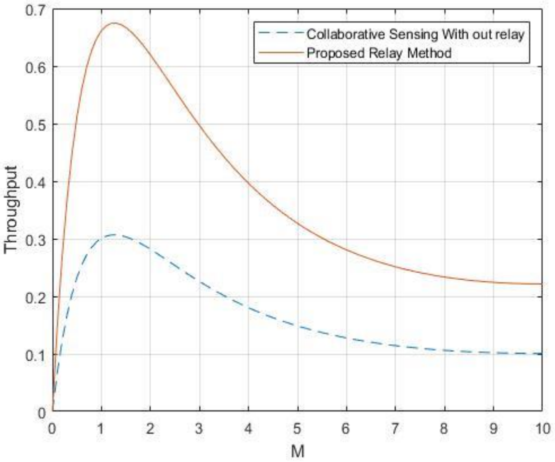

Fig. 6 Throughput of NB-CT-IoT network vs M

Fig. 7 shows the improvement of the network throughput in the relay-based NB-CR-IoT network using the collaborative sensing method with p_{fa}=0.1. Network throughput is improved compared to without relay because the distance between NU and SU is low, and SU uses a licensed spectrum. In this proposed relay-based network, a NU's transmitting power is lower, and NU battery life will be increased.

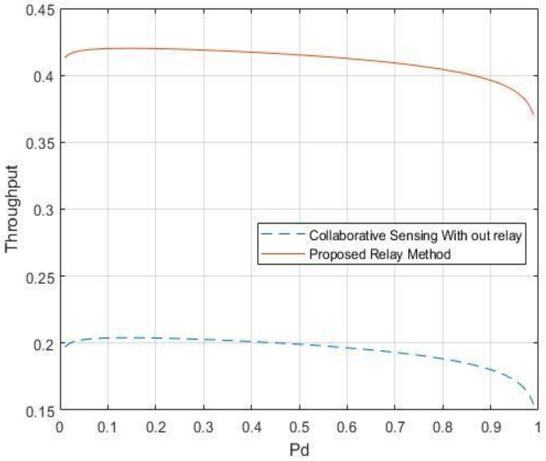

Fig. 7 Network Throughput vs P_d

5. Conclusion

In wireless networks, wireless collaborative sensing can better use spectrum resources. As we all know, the spectrum is band-limited. Therefore transmitting more distance-separated signals from one user to another requires more power. However, using relays between the devices reduces the power required to transfer the signals, which is more advantageous. By integrating the relay, the network throughput is enhanced.

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