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Wireless Energy Harvesting (Weh) and Spectrum Sharing In Cognitive Radio Networks

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ABSTRACT

It is detailed how one possibility exists for making use of wireless energy in the context of a decode-and-forward relay-assisted secondary user (SU) network that functions according to the guidelines of a cognitive spectrum sharing paradigm. The maximum power that the source and relay in the SU network can transmit from the harvested energy, the peak interference power from the source and relay in the SU network at the primary user (PU) network, and the interference power of the PU network at the relay-assisted SU network are the power constraints that were used to derive an expression for the outage probability of the relay-assisted cognitive network. According to the findings of the research, a relay-assisted network that makes use of the recommended wireless energy harvesting protocol has the potential to operate with an outage probability that is less than 20% for particular applications that take place in the real world. The performance limitation that was placed on the primary system is what is utilised to establish the optimisation challenge that has to be met in order to maximise the area throughput of the secondary system. After analysing the performance of the system with the help of the stochastic geometry theory, we developed a method that evenly distributes the available bandwidth and time resources in such a way as to make it possible for electromagnetic transmission as well as data transfer. Data on performance are provided to highlight how the various system parameters interact with one another and to assist with our theoretical research.

Keywords: Energy Harvesting, Cooperative Diversity, Spectrum Sharing, Stochastic Geometry, Cognitive Radio.

INTRODUCTION

The practise of energy harvesting has been proposed for use in a variety of contexts, either as a strategy for extending the useful life of batteries or as a source of alternative energy. The act of extracting energy from the environment in which we find ourselves is referred to as energy harvesting. Due to recent developments in embedded low power electronics, such as Micro-electromechanical (MEM) and low power wireless sensor network (WSN) devices, it is no longer possible for batteries with a finite energy capacity to serve as the primary energy source for a system over the course of that system's lifetime. This makes it impossible for batteries to serve as the primary energy source for a system. This makes it impossible for batteries to serve as the primary energy source for a system. Batteries are not suitable for use as the primary source of power for a system for this reason. This change has rendered it impossible for batteries to fulfil this role. Research into energy harvesting has been conducted for a variety of different energy sources, including thermal, solar, mechanical, acoustic, wind, and wave energy, to name just a few of them. In more recent times, research on energy harvesting has also been carried out for wireless communications. It has been proposed that point-to-point communication networks might benefit from the use of techniques that allow for the collection of wireless energy. The outcomes of the experiments suggested that wireless energy harvesting might provide a workable solution to the problem of prolonging the amount of time that energy-constrained equipment can be used. The investigation into this issue is focused on the sequencing of a data packet, with the energy harvesting and arrival rate being taken into account as part of the process. Nonetheless, the method of accumulating energy is not discussed in this text in any detail. The time switching relaying (TSR) protocol and the power splitting receiver (PSR) protocol are two examples of relaying techniques that were developed specifically for the purpose of wireless energy harvesting. Both of these protocols are relaying methods. The PSR protocol allocates a portion of the source's signal power for the purpose of energy harvesting and reserves the remaining signal power for use in the data extraction process. During the part of the TSR protocol that is devoted to energy harvesting, it is the responsibility of the relay to collect energy from the source signal. During the remaining period of time, it is the relay's job to collect data and transmit it to its intended location. In this step, expressions for the signal-to-noise ratios (SNR) and outage probability of both approaches are produced. The only component that can draw power from the wireless signal that the source emits is the relay, which also has a limit on the amount of energy it can store. The frequencies known as UHF and VHF are only two examples of the various signals present in the environment that have the potential to be used for the collection of wireless energy. In the context of cognitive radio, secondary users (SUs), also known as unlicensed users, have the capability to take energy from the signal that is being broadcast by the principal user (PU). This capacity is known as cognitive radio re-use. This concept is known as cognitive radio. In addition, the SUs has the option of using the licenced spectrum in one of two ways: either as an overlay or as an underlay [1]. Within the context of the cognitive radio overlay paradigm, the SUs are able to engage with one another anytime the licenced spectrum is accessible. Under the cognitive radio underlay paradigm, the SU network and the PU network are allowed to share spectrum; however, this is contingent upon the amount of interference caused by the SU network's broadcasts to the PU network not exceeding a predetermined threshold value. It is anticipated that relay-assisted cognitive radio will significantly cut down on the number of times that system problems occur. As part of this research project, one of the topics that will be fully investigated is the effect that power interference from a single PU transmitter has on the likelihood of a system outage in an SU network. This is one of the areas that will be investigated in depth. Researchers have researched the interaction between the interference power from the SU network on the PU network and the interference power from the SU network on the different PU transmitters that are on the SU network in order to generate a combined effect. This interaction is necessary in order to create a combined effect. This interaction is necessary in order to achieve a combined impact. This interaction is necessary in order to have an effect that is shared by everybody. In addition to the power interference limits, the relay-assisted cognitive radio has a limited amount of energy stored; as a result, additional charging methods would be required for it to continue running. The primary emphasis of the research being done right now is on understanding how cognitive radio operates within an underlying paradigm that makes use of energy harvesting. In this line of study, both the capacity of a point-to-point SU network with low CSI and the maximum rate that may be attained in an SU network via the use of opportunistic interference cancellation are under investigation. These two topics are related to one another. Additionally, the study examines the capacity of an SU network with bad CSI. The former is compared to the latter. To the best of our knowledge, there has not been any research conducted on the possibility of an outage occurring in a cognitive relay network that makes use of energy harvesting [2].

As part of this research, we provide a wireless energy-harvesting relaying protocol for a cognitive network. This protocol is intended for use with cognitive networks. This protocol allows for the transfer of data between nodes. This protocol lends further assistance to the processing and transfer of the information that has been conveyed. The proposed protocol states that the PU signal would be put to use in order to supply the cognitive network's source as well as its relay with the necessary amount of energy for them to function properly. We take into consideration the peak power that can be transmitted by the SU source and relay at the PU receiver, the maximum power that either the SU source or relay is allowed to broadcast by making use of the wireless energy that has been acquired, and the interference power that the PU transmitter will emit at the SU relay and destination. The subsequent explanation will focus on each of these components in turn. These three power limits and how they affect the likelihood of a system outage are taken into consideration. According to the results of the study, it is feasible to achieve an outage probability that is lower than 20% when the rate of energy conversion efficiency is increased. It should be noted that throughout this piece, the terms "SU network" and "relay-assisted cognitive network" are used synonymously. The remaining parts of this essay are organised as described below. The gearbox and the general architecture of the system work together to ensure that the power limitations imposed by the energy harvesting relaying protocol are strictly adhered to. Develop a formula to determine the likelihood of a problem occurring in the relay-assisted cognitive radio network [3], then use that formula to do the computation that was previously outlined. We will assume that there is one PU, one SU that is capable of energy harvesting, and one central entity that is responsible for regulating SU power in a CRN, as illustrated in Figure.

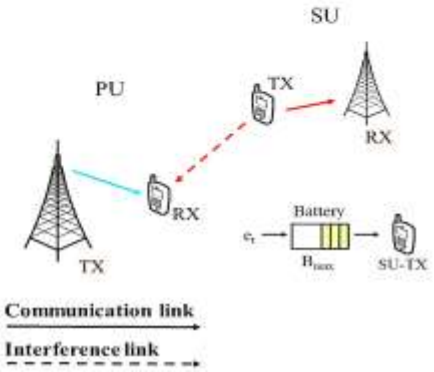

Figure. 1: The Su Is Able To Perceive And Gain Access To The Pu's Spectrum In An Advantageous Manner.

The SU makes use of a wireless sensor to collect information and energy from its environment and to deliver real-time updates on its state. After transmitting this data to its target, the SU waits for a 1-bit back signal. This signal informs the SU as to whether or not the status updates that it supplied were received successfully by the target. We take into consideration a time-sequencing system with time slots of t = 0, 1, and T 1. Markov chains and POMDPs, respectively, are used to represent the PU and SU models that go into the construction of the system model.

REVIEW OF LITERATURE

In a cognitive spectrum sharing network that makes use of decode-and-forward relay support for secondary users (SU), it is recommended that a technique of wireless energy harvesting be implemented. This network must function in accordance with these limits. In a cognitive spectrum sharing network that makes use of decode-and-forward relay support for secondary users (SU), it is recommended that a technique of wireless energy harvesting be implemented. All three of these power constraints are taken into account in the calculation. According to the results, a relay-assisted network that makes use of the recommended wireless energy harvesting protocol may be able to operate with an outage probability that is less than 20% for a range of applications that are used in the real world. [4].

Sharing of frequency spectrum may be an answer to the problem of a lack of available frequency spectrum. The breakthrough This will allow the ideal policy to be established. This is done in order to arrive at the best policy that can possibly be devised. Reducing the typical area of influence (AoI) of the secondary user can be accomplished by picking the optimal course of action for each time slot, taking into account the specifics of the situation, and carrying out these actions in both the overlay and underlay modes. In the end, simulated workouts are used to determine whether or not the proposed scheme is effective in regard to the overlay mode. According to the findings, the recommended system has a lower average AoI than any of the available models, even the one that only considers the overlay mode. This is the case regardless of which model is being compared. The average user access in the DQN and D3QN climbed to 45% and 48%, respectively, when the respective networks were utilised, up from 30% in the overlay mode when neither network was utilised [6].

Within the context of a cognitive radio network that makes use of wireless energy harvesting (EH) and that organises all primary and secondary users on a two-dimensional plane in a hierarchical fashion, we investigate the concept of cooperative spectrum sharing. It is predicted that each principal user (PU) would be able to manufacture energy from the wireless signal that is given by its associated access point (AP), while all access points (APs), as well as secondary users, will get a steady supply of power. This will allow for the PUs to generate their own power independently of the APs. In order to improve the efficiency of the EH, a zone is created all the way around each PU, and the secondary transmitter (ST) that is located in the closest proximity to the PU is selected to be in charge of distributing wireless energy inside this zone. It is possible for the PU to transmit data to the AP through the reverse link by using the energy that was acquired; but, because to the low transmission power and severe pathloss, there is a greater probability that the data transfer may fail. In this scenario, the primary data is sent to the AP through the channel that offers the highest throughput on the applicable ST, and a cooperative region is used between each PU and the AP that is associated with it. It may not be difficult to satisfy the performance requirements of the primary system with the assistance of ST cooperation, which would free up some bandwidth for the transmission of secondary data [7]. Additionally, this may make it possible to more easily meet the needs of the secondary system. If this is the case, the main system will benefit greatly from this development. The limitation placed on the primary system's performance is what is utilised to establish the optimisation challenge that must be solved in order to optimise the secondary system's area throughput. With the help of stochastic geometry theory, we were able to do an analysis of the performance of the system, which allowed us to build a method that makes effective use of the available bandwidth and time resources to facilitate electromagnetic transmission as well as data transfer. This was accomplished by effectively distributing the available bandwidth. Our theoretical investigation is complemented by the performance data that are reported here [8], which demonstrate how the values of various system parameters have an effect on the system as a whole. The purpose of this research is to provide a separate best cooperative method (BCM) for the wireless energy harvesting and spectrum sharing that is required of 5G networks [9]. The transmission of data and the collection of energy are both finished inside the allotted time window. Energy for the planned BCM's secondary users (SUs) comes not just from the surrounding ambient signals but also from the signals produced by the principal users (PUs). Additionally, the SUs have the potential to act as PU relays while simultaneously accumulating energy from PU signals. The approach that has been provided ensures that the data transfer will be carried out in the most efficient and timely manner possible within the constraints of the allotted amount of time. In order to increase the throughput of both the PU and the SU while also setting restrictions on the data rate and the energy harvesting efficiency ratios, we create an optimisation problem based on the suggested BCM. In order to prove that the hypothesised cooperative mechanism is effective, which is an essential first step in the process of advancing the research of this topic, simulations are used. [10].

SYSTEM MODEL

As can be seen in Figure 2, the PU network is made up of a PU transmitter that goes by the name of P Tux and a PU receiver that goes by the name of P Urx. In the SU network, which consists of one source (S), one relay (R), and one destination (D), the only way information can be sent from an energy-constrained source to the destination is via an energy-constrained relay at some point in the network. This is the only method information can be conveyed from an energy-constrained source to the destination. This is the sole method that is capable of successfully transmitting information from an energy-constrained source to its destination. This method is the only one that has been shown to successfully transfer data from an energy-constrained source to its intended destination. This method has been shown to be the only one that is capable of successfully transporting data from an energy-constrained source to the receiver that it is meant for. There is only a thin connection between where we came from and where we want to go, and the two are quite different places. The amount of power that can be extracted from the PU is information that can be accessed by both the source and the relay. This information is disseminated. This applies to both the source and the relay. However, we are going to assume that the SU network is unable to store the energy that has been gathered for an extended amount of time. Despite the fact that energy is lost via leakage, this assumption is correct for SUs that have inexpensive capacitors installed for the aim of using them as energy storage devices. When an underlay mode is used, both the secondary user network (SU) and the primary user network (PU) will share the same frequency spectrum. Channel gain coefficients that go from the source to the relay are often referred to as "H1," whereas channel gain coefficients that travel from the relay to the destination are typically referred to as "H2."

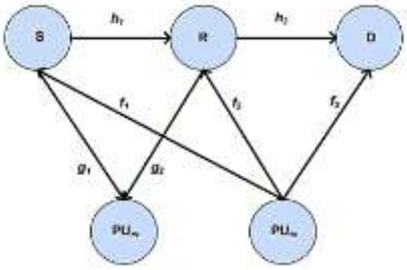

Figure 2: System Model

Since the transmission power from the SU network has the potential to interfere at the PU receiver, a power limitation has been set on the SU network in order to prevent its interference power from exceeding the maximum interference power that is permitted, which is indicated by PI. This will prevent its interference power from exceeding the maximum permissible interference power. By following these methods, you may assure that the interference power will not exceed the range that is permissible. In relation to the PU receiver, the phrases "G1" and "G2" refer to the channel gain coefficients that, respectively, stand for the source and the relay. These coefficients are denoted by the terms "G" and "G" correspondingly. It's possible to abbreviate phase-locked loop as PU, which stands for the acronym. The amount of power that a specific source and relay are able to take from the power grid is directly proportional to the quantity of energy that they have accumulated throughout the course of the transmission, which is represented by Ehs and Ehr, respectively. This energy has been gathered over the course of the transmission. This is the case because the amount of power that they are able to draw is directly proportional to the amount of energy that they have acquired. This information is used to calculate the amount of power that can be drawn from the power grid. The channel gain coefficients F1, F2, and F3 are sent by the PU transmitter to each of the three receivers: the source receiver, the relay receiver, and the destination receiver. The PU transmitter is situated at a location that is d1 kilometres away from the source, d2 kilometres away from the relay, and d3 kilometres away from the destinations. The following is a breakdown of the PU network interference power that affects both the relay and the destination:

$$P_{\mathrm{I},R} = \frac{P_P U_{tx} |f_2|^2}{d_2^m}$$

$$P_{\mathrm{I},R} = \frac{P_P U_{tx} |f_3|^2}{d_2^m}$$

where m represents the route loss exponent and P_{PUtx} represents the power output by the PU transmitter. When a new time slot begins, the source and the relay will begin to receive energy from the PU signal for a period equal to T, where T is the length of one time slot and 0 1 is the commencement value. This will take place for the duration of the whole time slot. This will happen whenever a new time slot begins. This will continue for the duration of the time slot. Altering the value of may be one way for the source and the relay to strike a compromise in order to achieve their goal of increasing energy collection while simultaneously decreasing throughput at the destination over a certain amount of time. This essay will not cover the selection of and how either it or its effects will affect the functioning of the relay network for a number of reasons. We are looking at the idea that the relay might also get its power from the source. After the time allotted for harvesting, the source stays in communication with the relay for an amount of time that is equal to T 2 plus one. After then, the information is sent to the destination by using the relay.

PU Model

It is possible for the PU to be either active (A), in which case it is transmitting information, or idle (I), in which case it is not since it has full and unrestricted access to the spectrum. Both of these states are indicated by the capital letter A. This would result in the formation of a Markov chain, the component states of which would be not and A, I. This would lead to the construction of a Markov chain. It is common practise to use the two-state (active or inactive) Markov chain model in order to carry out simulations of the operations carried out by the PU. This model may either be active or dormant depending on the circumstances. The probabilities of remaining in the inactive state, changing from the active state to the inactive state, changing from the inactive state back to the active state, and changing from the active state back to the inactive state, respectively, are referred to as the PII, PAI, PAA, and PIA transition probabilities for the Markov chain that represents the PU. These probabilities are represented by the letters I, P, A, and A, respectively. There are other transition probabilities that include remaining in the active state as well as transitioning from the active state to the inactive state. These probabilities also take into account the chance of transitioning back from the active state to the inactive one after having been in the active one.

Data Transmission Model

where equal-sized chunks of time are employed to divide up the data transmission period. The addition of the parameter results in each normalised block being further partitioned into three portions. During the first part of each gearbox block, it is the responsibility of the AP to carry out the WET across the forward link. After successfully collecting energy during time fractions 1 and 2 of the time period, the PU is going to send a data packet via the reverse connection. If the first data packet was successfully received by the AP, the AP will proceed to send out a second data packet at the final time fraction 12 of the total time fraction, as seen in Block m of Figure 3 and Block m. This will take place only if the first data packet was received by the AP. This occurs in the event that the first data packet was properly received by the AP. This will occur only if the first data packet was properly received. This will take place only in the event that the first data packet was properly received. On the other hand, in the event that the first data packet is accidentally sent to the access point (AP), a copy of it will be resent in the final time fraction 12 as a precautionary measure. In order to determine which data packets contain the primary information, the AP applies a maximum ratio combination (MRC) algorithm to both the original and the retransmitted ones.

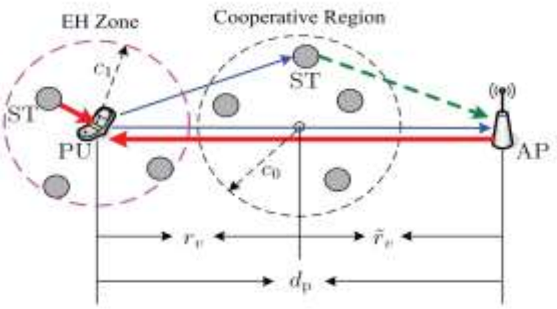

Figure 3: The Eh Link Is Shown By the Thick Red Line, and the Possible Retransmission Is Shown By the Dashed Green Line in This Diagram.

As can be seen in Figure 3, we establish an EH zone all the way around each PU with a radius equal to c1. The ST in the EH zone that is physically closest to the PU is the one that will be picked to be the device that simultaneously transmits RF energy and the AP within the given time fraction. This will ensure that the PU receives the strongest possible signal. The AP will be able to wirelessly transmit energy to the PU on its own within the given time fraction even if there are no STs present in the EH zone if the PU has no STs nearby and there are no STs present in the EH zone. As shown in Figure 3, we initiate the formation of a cooperative zone that has a radius of c0 and is centred on the line that runs between the AP and the PU. The primary data are sent in the remaining time fraction 1 with the assistance of STs that are located in the cooperative region and via the implementation of the incremental relaying protocol. Because wireless channels are broadcast, the data that is sent by the PU may be received by all of the STs that are located within the cooperative region. STs are considered to be candidates for potential ST status if they are able to decode the main data collected in the cooperating region. In the event that the AP correctly reads the most recent data packet, the PU is going to transmit another data packet. In the event that this is not the case, the initial info is resent towards the AP utilising the most likely ST that have the highest channel quality. In the event that there are no operational STs in the region in which the participating PU is located, the PU will retransmit the primary data it has. Because the SUs have the potential to significantly enhance the primary system, just the bandwidth range 0–1 is required to carry primary data when using cooperative approaches. This is because of the cooperative nature of the approaches. The remaining portion of the discontinuous bandwidth 1 is being leased to the secondary data transmission in order to guarantee that everyone who contributed to the project will be compensated for the amount of time and effort they put into it. When either the radius of the EH zone is set to zero or when c1 is equal to zero, it is feasible to have data transmission that is both wet and cooperative. This is because both of these conditions make it conceivable for c1 to be equal to zero. When the radius of the cooperative zone is zero, which is also expressed by the notation c0 = 0, it is possible to employ either the cooperative WET technique or the noncooperative data transmission method. Both of these approaches are described in detail below. Both of these approaches are described in detail below. Both of these methods are described in detail below. When both the radius of the EH zone and the radius of the cooperative area are set to zero, the data may be provided either cooperatively (through the use of WET) or non-cooperatively (via the use of data), depending on the mode that has been chosen.

RESEARCH METHODOLOGY

For the purpose of determining the recommended BCM's level of effectiveness, we tested it on a cognitive 5G network, a PU network, and an SU system. When there is one-to-one spectrum sharing and energy harvesting, the employment of one PT/PR and one ST/SR as essential components is needed. These components must be used simultaneously. These components must be used simultaneously. On the other hand, we can decide to improve the prototype of this simulation model to one that is more accurate. We compare and contrast the already implemented systems with the BCM that we propose. The non-cooperative mode is referred to as Type A, while the plain cooperative version is referred to as Type B. Both types are described further below. The following is a description of each of the two categories. Before the SU starts broadcasting, the Type A PU will have completed transmitting all of the data to the receiver of the Type A PU. In Type B, the SU starts transmitting immediately after the PU. SU and PU may collaborate in a kind of cooperative protocol known as kind B in order to extend the battery's life and evenly distribute its power for SU's throughput. The simulation settings that we use for CSO are as follows: A memory pool search (with the parameter SMP = 6), a range search (with the parameter SRD = 0.2), a mode ratio search (with the parameter MR = 0.8), and a constant factor search (with the parameter c = 2) are carried out. The component that remains constant is two, whereas the other half of each dimension is open to variation. The population size, denoted by the letter H, will be changed to 300, and the inertia weight, denoted by the letter Wt, will be reduced from 0.9 to 0.4. Both of these changes will take effect immediately. The number 100 has been chosen as the maximum number of iterations. The results of the simulation are shown in Table 1, along with the various parameters.

Table 1: Simulation Parameters For The Cso.

Parameter	Value
constant component (c)	3
Dimensional changes expected (CDC)	0.6
Memory pool size (SMP) search	5
Trying to find the chosen dimen-sion range (SRD)	0.3
MR, or mixture ratio	0.7
Weight of inertia (w1)	decrease from 0.8 to 0.5
(H) Population size	400
Maximum number of iterations	200

T has the value of 1, and Xp remains unchanging throughout. For the purposes of the proposed BCM, we will make the assumption that PU has a minimum throughput that is either equal to or higher than that of types A and B during each timeslot. According to the findings of a number of numerical simulation tests that were carried out with the assistance of the mathematical programme MATLAB, the best strategy for each resource that the SUs leased may alter over time when using the differential game model that was previously created and solved. This is the case when employing the model. In the next part, which follows this one, we are going to look at the open loop Nash equilibrium solution to the differential game model in further depth. Initially, we will go through our findings, and then we will proceed to provide some guidance to SUs on the spectrum band resource that is now being leased. The simulations make use of three SUs in order to build the environment for the simulations, which is based on the differential game model that was provided, and to demonstrate how the system strategy, which may be dynamic. This is accomplished by configuring the simulation environment. This is done so that the results of the simulations can be more accurately interpreted. This is carried out in both a feedback setting as well as an open loop setting. The simulation parameters for the differential game model that were utilised in the experiment are listed below in Table 2, which can be found below.

Table 2: Simulation Parameter Settings for Various Game Models.

Parameters	**I**	Ωdisi	ωehi	ωspi	Bi	εi	Hi	**r**	πp	Δ	αi	Φi	**T**
Value	1	0.5	0.9	0.2	0.2	0.4	0.29	0.16	0.3	−0.16	−0.7	0.2	100
Value	2	0.6	0.3	0.4	0.5	0.6	0.06	0.16	0.3	−0.16	−0.6	0.5	100
Value	3	0.7	0.2	0.5	0.6	0.7	0.35	0.14	0.3	−0.16	−0.5	0.9	100

On the other hand, in order to simplify the simulations, we take into consideration some unusual occurrences. One example of this is when we find that certain elements, such as the discount rate r, the unit price p, and the spectrum loss rate during the process of spectrum leasing, are the same for all three customers. This happens when we discover that certain values are shared by all three users. If one first conducts an analysis of the open loop solution and the feedback solution of the differential game model that is given in this work, it is possible to determine the optimal formulation of SU's resource allocation strategy in relation to the open loop Nash equilibrium and the feedback Nash equilibrium. This will allow one to determine whether or not it is possible to identify the optimal formulation of SU's resource allocation strategy. This can be done if one follows the steps outlined in the previous section. It is possible to achieve this goal by following the steps outlined in the section that came before this one. After that, it is possible to find both the open loop Nash equilibrium as well as the feedback Nash equilibrium.

ANALYSIS AND INTERPRETATION

Researching new businesses, which are often seen as the A typical SU with regard to the PU's highest possible transmit power. Since the average rate is higher than the rate that was used as a baseline rate, it is possible to draw the conclusion that the SU in the situation that has been described has access to the spectrum that is more advantageous than average. An increase in transmit power results in an increase in the chance that the silent mode will occur rather than the potential that the baseline overlay mode would occur. This occurrence takes place more often than the overlay mode in the baseline, which takes place a less percentage of the time. On the other hand, it is clear that in the hypothetical situation, the possibility of the underlay mode increasing while the chance of the overlay mode decreasing. This can be observed by comparing the two modes. This is the case because the chance of the underlay mode increases. After that, there is a greater possibility of operation in the quiet mode, but there is a decreased possibility of operation in the underlay mode. According to the statistics, it starts sending data with decreased power in the majority of cases when the power level of the user is 15 dBm or greater. This is due to the fact that at such levels, it is more probable that the user will be in the underlay mode. Despite the fact that customers often transmitted data while using the highest power in the overlay mode, the rate has dropped in comparison to earlier powers. The recommended system, on the other hand, surpasses the baseline condition in terms of rate, and the D3QN has a rate that is just slightly higher than the rate of the DQN. This holds true even when operating at high powers.

Table 3: Comparison of Dqn and D3qn Using the Baseline

Power of PU (dBm)	**Rate(bps/Hz)**		**AoI**	
	DQN	***D3QN***	***DQN***	***D3QN***
0	56.60%	59.50%	-35.20%	-40.50%
5	55.60%	61.70%	-32.80%	-36.60%
10	52.40%	62.20%	-36.50%	-37.80%
15	30.60%	35.30%	-35.70%	-38.80%
20	21.90%	35.90%	-32.80%	-38.80%

Table 3 presents a numerical comparison of the data regarding the rate and AoI with regard to the baseline for the planned DQN and D3QN. According to the data, the percentage of users who had access to the spectrum ranged from 35% in the case of the baseline scenario to 42% in the case of the proposed DQN scenario and 49% in the case of the D3QN scenario. In the D3QN scenario, the average percentage of users who have access to the spectrum is 49 percent.

This is the fraction of users who have access. This demonstrates that there is a very significant reduction in the amount of AoI in the environment nowadays.

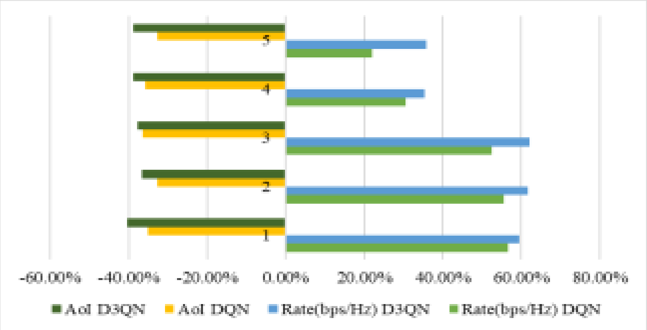

Figure 4: Dqn and D3qn Comparison Based On the Baseline

Because of this, the pace is far slower than it was in prior powers, despite the fact that the user often sent data while making use of the power's full capacity in previous powers. The recommended system, on the other hand, surpasses the baseline condition in terms of rate, and the D3QN has a rate that is just slightly higher than the rate of the DQN. This holds true even when operating at high powers.

Table 4: Comparison Based On the Baseline of Dqn and D3qn

Power of SU (dBm)	**Rate(bps/Hz)**		**AoI**	
	DQN	***D3QN***	***DQN***	***D3QN***
0	55.60%	59.90%	-32.20%	-50.50%
5	54.70%	65.70%	-35.80%	-56.60%
10	56.40%	64.20%	-38.50%	-37.90%
15	33.60%	35.60%	-35.90%	-39.80%
20	31.80%	35.70%	-32.60%	-38.90%

Table 4 presents a numerical comparison of the data regarding the rate and AoI with regard to the baseline for the planned DQN and D3QN. According to the data, in the baseline scenario, 41% of users had access to the spectrum on average; however, under the proposed DQN and D3QN scenarios, respectively, 48% and 52% of users had access to the spectrum under those scenarios. This demonstrates that the amount of AoI in the environment has significantly decreased.

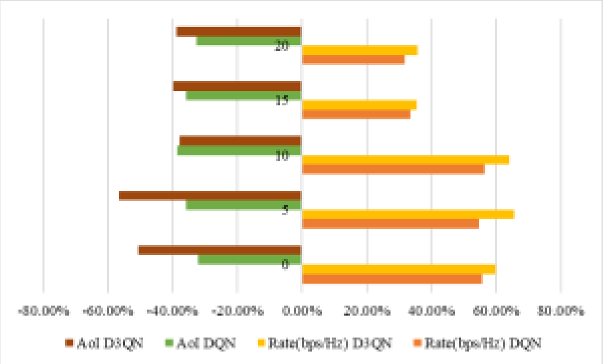

Figure 5: Comparison of Dqn and D3qn With Regard To the Baseline

RESULT AND DISCUSSION

The proposed model is a system that incorporates both the overlay and underlay modes, while the baseline model is a system that only employs the overlay mode. The proposed model was offered as an alternative to the baseline model. The baseline model is referred to as the "overlay mode only" model. Both modes are included in the system that was introduced. Figures 6 and 7 illustrate the evaluation as well as the convergence of artificial intelligence that is applied for a variety of techniques. In order to facilitate comparison, Figure 6 depicts the proposed reward function for the Poisson and Normal energy distributions for the same battery capacity.

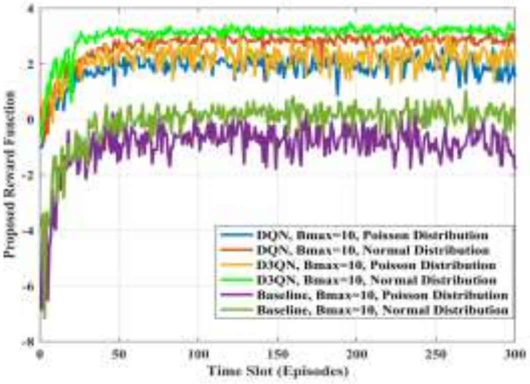

Figure 6: The Proposed and Baseline Reward Schemes Work.

Due to the fact that the AoI in each technique was modified, the reward for the proposed instance is greater than the reward for the baseline scenario. Figure 7 depicts the reward function that should be used for various energy distributions when utilising two different battery capacities. As a consequence of this, changes in the battery capacity have an effect on the AoI.

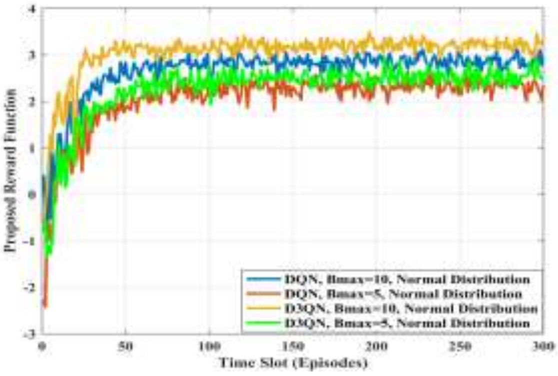

Figure 7: The Proposed Scheme's Reward Function Has Bmax = 10, 5 Mah.

CONCLUSION

During a discussion on a wireless energy harvesting solution for a relay-assisted network, the possible implementation of a cognitive spectrum sharing paradigm was brought up as a point of concern that should be taken into account. When doing an analysis of the relay-assisted cognitive network's outage probability while employing the recommended protocol, a range of factors from a large number of different categories were taken into consideration. Some of these problems were an inability to gather energy, interference power constraints on the primary user network, and interference between the primary user cognitive network and the secondary user cognitive network. Simulations carried out on a computer were the primary method of data collection employed in the process of developing and validating a sensitivity analysis for the possibility of a power outage. According to the results, it is possible to achieve an outage probability of less than 20% by increasing the pace at which energy is converted into another form. Within the context of this system, it is the responsibility of the SU to choose an action xt that reduces the AoI in a manner that is proportionate to the power received from the PU and the energy that is stored in the battery, but does so in a manner that is completely unrelated to the PU. To put it another way, the AoI has to be decreased in such a manner that it becomes proportionate to both the amount of energy that is stored in the battery and the amount of power that is obtained from the PU. The findings of the simulation indicate that the baseline model, which only contains overlay mode, shortens the amount of time that the SU is able to use the spectrum. On the other hand, the recommended system model lengthens the amount of time that the SU may spend using the spectrum. This pertains to the fact that the overlay mode of the baseline model is the only mode that can be found in the environment. In addition, D3QN beats DQN not just in terms of performance but also in terms of the pace at which it converges. Because of this, the Area of Interest (AoI) reduces much more when using the underlay mode as opposed to the overlay method. Additionally, it is believed that the normal distribution, when used as the energy distribution, generates findings that are more accurate than when the Poisson distribution is used.

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