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Implementation of Cognitive Wireless Sensor Network with Energy-Aware Cooperative Spectrum Sensing by Different Censoring Techniques

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Abstract**:** *Energy conservation is needed as the cognitive wireless sensor network's lifetime depends on energy. The cooperative spectrum sensing technique is that remote sensors participate and share their detecting data and send their outcome to the fusion center to improve the detecting execution and exactness. This work aims to lessen vitality utilization in helpful range detecting by different techniques, for example, Knapsack-based Energy Efficient Node Selection Scheme (KEENSS) and censoring and sleeping scheme. KEENSS diminishes the vitality expended for revealing range detecting results to the fusion center. The node selection issue is defined as a backpack issue and to infer its solution by distance calculation and weight allocation. The energy of KEENSS is calculated by considering transmit energy, sensing energy, and the path loss exponent for different environments. A combined censoring and sleeping scheme is proposed where each sensor kills its detecting module with a sleeping rate likelihood at each detecting period on account of the sensor is on, a censoring policy arrangement is utilized to send the decisions to the fusion center. The network energy consumption is limited depending on the detection probability and false alarm derived for AND rule and OR rule and by considering censoring and sleeping rate. The simulation result shows that reduced energy consumption is obtained using a combined censoring and sleeping scheme of 143 nJ and 157 nJ for AND fusion rule and OR fusion rule, respectively, while KEENSS provides energy consumption for five selected nodes 379 nJ and 14 selected nodes is 690 nJ. The simulation result of the report time-saving ratio for OR rule is 0.2207 and for AND rule is 0.3289. The simulation result shows that reduced energy consumption is obtained using combined censoring and sleeping scheme in which AND rule outperforms OR rule for a lower value of probability coefficient as 0.2, and the OR rule outperforms AND rule for a higher value of the probability coefficient as 0.8.*

Keywords: *censoring and sleeping rate, Weight allocation, Energy-saving ratio.*

I. INTRODUCTION

In common, spectrum shortage is a significant issue in wireless sensor networks. To defeat the spectrum shortage issue in a WSN, Cognitive Wireless Sensor Network (CWSN) has been offered. Cooperative spectrum sensing is considered the answer for defeat issues, such as blurring and shadowing impacts and expanding the detecting execution. In cooperative spectrum sensing, each sensor decides the channel status and sends its outcome to the Fusion Centre (FC). The FC makes the final decision about the channel based on the receiving results and a fusion rule. For cooperative spectrum sensing, the OR rule is utilized in FC in which if at any rate one sensor reports that the essential client is dynamic, the ultimate conclusion implies the channel is occupied. Different plans execute energy-saving cooperative spectrum sensing in cognitive wireless sensor networks, such as knapsack-based energy-efficient node selection schemes and censoring and sleeping schemes.

Knapsack-based energy-efficient node selection scheme lessens the energy devoured for revealing range detecting results to the fusion center. Picking the number of CWSN nodes for CSS with sensing reliability subject to energy limitations will decrease the misuse of assets such as energy and bandwidth. A combined censoring and sleeping scheme for energy-efficient spectrum sensing by keeping up the limitations on detection probability and false alarm by ideally planning the sleeping and censoring thresholds. Fusion center makes the decision based on AND rule and OR rule.OR rule states that any one of the nodes sense that the essential client is available, Fusion center makes a final decision that essential client is occupied.AND rule states that all the nodes in the network report that an essential client is available, Fusion Center creates a final decision that the essential client is occupied. Md. AlimulHaque et al. have contemplated the fundamental idea of cognitive wireless sensor networks and discuss the taxonomy of assaults such as communication assaults, privacy assaults, node targeted assaults, power consumption assaults, policy attacks, and cryptographic attacks and their counter measures. [2]. Maryam Monemian et al. (2016) have offered a cooperative spectrum sensing to improve the dependability of choices made about essential clients' nearness in cognitive radio networks. Reduced energy consumption for cooperative spectrum sensing is a challenging issue that should be solved by effectively managing sensors for cooperative spectrum sensing. The paper defines that all the subsets of sensors that cooperatively satisfy the desired sensing precision are designed. A heuristic algorithm is proposed which chooses the subset with minimum average energy consumption for cooperative spectrum sensing. [7].

SinaMaleki et al. (2013) depict the development in the cooperation overhead of framework by increasing the number of cognitive radios. The development of the cooperation overhead leads to a throughput deprivation of the cognitive radio network. Throughput optimization of the hard fusion-based detecting utilizing the kk-out-of-NN rule is considered. The throughput of the cognitive radio network is augmented to determine the ideal number of clients, the ideal kk, and the best false alarm probability. [21]

II. ENERGY EFFICIENT COOPERATIVE SPECTRUM SENSING

A. *KNAPSACK BASED ENERGY EFFICIENT NODE SELECTION SCHEME (KEENSS)*

The knapsack problem is an advancement issue, given a set of nodes, each with a weight and a value, decide the number of nodes to remember for an assortment, the total value is maximum as possible, and the total weight is less than or equal to a given limit.Fig.1 shows the block diagram for knapsack-based energy-efficient node comprises cooperative spectrum sensing environment followed by distance calculation for every node and then weight allocated for every node based on the distance calculated.

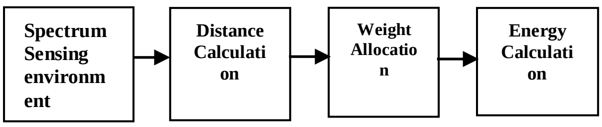

Fig.1 Block diagram for knapsack based energy-efficient node selection scheme

Weight allocation is based on the distance between the primary user and nodes. Energy calculation is based on the selected nodes from total nodes, path loss exponent for various environments, and distance between the nodes and fusion center.

a) Cooperative spectrum sensing configuration

The cooperative spectrum sensing setup contains an N sensor node, an essential client (primary user), and a fusion center in the center. Accept that the sampling frequency and sensing time are the same for all sensors. The essential client signal is a QPSK modulated signal with a bandwidth 6 MHz; the sampling frequency is the same as the bandwidth of the essential client. Here, each sensor chooses the channel status and sends its outcome to the FC. The FC makes the final decision about the channel based on the receiving results and a fusion rule.

b)Distance calculation

The distance between essential clients and nodes and the distance between nodes and fusion center is calculated using the distance formula. The distance is calculated by

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

From (1), (x_1, y_1) is the location of the primary user, while considering the distance between fusion center and nodes, (x_1, y_1) is the location of fusion center. $(x_2, y_2)$is the location of node.

c) Weight allocation

Weight allocation for the sensor nodes is allocated based on the distance between the essential client and nodes. For allocating weight for each node based on distance, the maximum allowable distance of a square field is the diagonal of a square. The diagonal of a square is calculated using the formula,$Diagonal(d) = \sqrt{2}a$(2)

Table.1 Weight Allocation of KEENSS

Distance	Weight
0 ≤ D ≤ 0.25 d	4
0.25 ≤ D ≤ 0.5 d	3
0.5 ≤ D ≤ 0.75 d	2
0.75 ≤ D ≤ d	1

As in Table.1, the weights are allocated for every node. For the minimum distance between the essential client and node is allocated with maximum weight, and for maximum distance between the node and essential client is allocated with minimum weight. For a set of P selected nodes out of N nodes where P can be not exactly or equivalent to N, the total energy consumption can be written as in (3),

$$E_{total} = P(e_r + e_s) + \sum_{j=1}^{P} e_t^j \quad (3)$$

Here, the fusion center gets the nearby choice (local decision) from each node, receiver energy is assumed to be constant. The total energy consumption is given as in (4),

$$E_{total} = P(\tau + \varepsilon d_j{}^{\alpha}) \quad (4)$$

Where P selected nodes out of N nodes, P<=N, $\tau = e_r + e_s$, ε is the power model constant, d_j is the distance between node and fusion center, α is the path loss exponent.

B. COMBINED CENSORING AND SLEEPING SCHEME

By using this scheme, energy-efficient spectrum sensing is acquired by fulfilling the detection performance constraints. The detection threshold is acquired from the energy detection scheme for signal detection. Fig 2. Shows the steps involved in this scheme. The cooperative spectrum sensing input is the same as previously used.

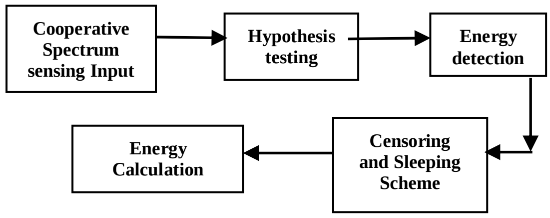

Fig.2 Block diagram for combined censoring and sleeping scheme.

Hypothesis testing

Spectrum sensing causes auxiliary clients to recognize the nearness of essential signs to ensure the essential client transmission. The null hypothesis denoted by H_0 relates to the nonattendance of the essential client's transmission, i.e., the received signal being only noise. On the other hand, the alternative hypothesis denoted by H_1 indicates that the primary user's transmission is present, i.e., the received signal contains the primary signal and noise. The goal of a binary hypothesis test is to check the spectrum is idle or busy. A binary hypothesis test for detecting essential client's transmission is given in equation (5) and (6),

$$H_1: X_j[k] = h_j[k]s[k] + u_j[k] \quad (5)$$
$$H_0: X_j[k] = u_j[k] \quad (6)$$

where $X_j[k]$ is the receiver signal, s[k] is the essential client signal, which is thought to be deterministic: h_j is the channel gain between each node and the essential client.

Energy detection

Energy detection is a non-coherent detection method that is frequently used if the receiver cannot collect enough information about the essential client signal. The energy detection scheme is used for signal detection for the *j*th sensor is given as in equation (7),

$$E_j = \sum_{k=1}^{\delta f_s} X_{jk}{}^2 \begin{matrix} > H_1 \\ < H_0 \end{matrix} \lambda$$
$$D_j = 0 \; if \; H_0; D_j = 1 \; if \; H_1 \quad (7)$$

where λ is the censoring threshold.

If the energy of the receiving samples is greater than λ the channel will be busy (*Dj*= 1); otherwise, the channel will be idle (*Dj*= 0).

False-alarm probability states that the probability in which the channel is considered busy while it is idle. It shows missing the opportunity of using the spectrum. The false alarm probability is defined in equation (8),

$$P_{f_j} = P\left(E_j > \epsilon | H_0\right) = \frac{\Gamma\left(\delta f_s, \frac{\epsilon}{2}\right)}{\Gamma(\delta f_s)} \quad (8)$$

where δ is the sensing time, f_s is the sampling frequency of the received signal from the essential client, $\Gamma(a,b)$ is the generalized Marcum Q function.

The detection probability is the probability that the channel is considered busy when it is really busy. This probability protects the transmission of the essential client from the interference produced by the optional client. The detection probability is defined in equation (9),

$$P_{dj} = P\left(E_j > \epsilon | H_1\right) Q_{\delta f_s}\left(\sqrt{2\gamma_j}, \sqrt{\varepsilon}\right) \quad (9)$$

where, $Q_m(a,b)$ is the generalized Marcum Q-function, γ_j is the primary-user SNR in the *j*th sensor under the hypothesis H_1.

Combined censoring and sleeping scheme

To accomplish a higher energy saving, censoring, a sleeping policy is applied. Each sensor turns off its sensing module randomly with a sleeping rate denoted by μ. Denoting by sensing energy *Cs* and transmitting energy *Ct* the energy consumed by the *j*th radio in sensing per sample and transmission per bit, respectively, our cost function is given by the average energy consumption per sensor as follows as in (10),

$$C_j = (1-\mu)(NC_s + C_t(1-\rho_j)) \quad (10)$$

where $\rho_j = P_r(\lambda_1 < \varepsilon_i < \lambda_2)$ represents the censoring rate. It is presumed that $\mu \neq 0$ and $\rho_j \neq 0$. The transmission and sensing energy of the sensors is assumed to be the same. The censoring rate is given as

$$\rho_j = \pi_0 P_r(\lambda_1 < \varepsilon_j < \lambda_2 | H_0) + \pi_1 P_r(\lambda_1 < \varepsilon_j < \lambda_2 | H_1) \quad (11)$$

$$\rho_j = \pi_0 \delta_{0,j} + \pi_1 \delta_{1,j} \quad (12)$$

OR Rule

The Fusion center utilizes the OR rule to make the final decision. Denoting D_{FC} to be the decision made at the fusion center, the OR rule means that $D_{FC} = 1$ if at any rate, one node sends a 1, else $D_{FC} = 0$. The global false alarm probability $Q_{F,OR}$ for the OR rule is obtained by using 13,

$$Q_{F,OR} = P_r(D_{FC} = 1|H_0) = 1 - [1 - (1 - \mu)\mathrm{P}_{\mathrm{f,j}}]^M \quad (13)$$

where $\mathrm{P}_{\mathrm{f,j}}$ is the false alarm probability. The global detection probability for the OR rule can be derived similarly and results in equation 14 as,

$$Q_{D,OR} = P_r(D_{FC} = 1|H_1) = 1 - \prod_{j=1}^{M}[1 - (1 - \mu)\,\mathrm{P}_{\mathrm{d,j}}] \quad (14)$$

where $\mathrm{P}_{\mathrm{d,j}}$ is the detection probability

AND Rule

According to the AND rule, $D_{FC} = 0$ if at least one cognitive radio reports a zero, else $D_{FC} = 1$. The global probabilities of false alarm and detection are obtained as in equation 15 and 16,

$$Q_{F,AND} = P_r(D_{FC} = 1|H_0) = [1 - (1 - \mu)(1 - \delta_0 - P_{f,j}]^M \quad (15)$$

$$Q_{D,AND} = P_r(D_{FC} = 1|H_1) = \prod_{j=1}^{M}[\mu + (1 - \mu)(1 - \delta_{1,j} - \mathrm{P}_{\mathrm{d,j}}] \quad (16)$$

Note that for the AND rule, the FC thinks about any outcome except for 0 as 1. In this way, from the FC perspective, a false alarm or detection at the j^{th} cognitive radio occurs if the received result is not 0 when the essential client is absent or present.

Energy calculation

The Total Energy for Censoring and Sleeping Scheme is calculated as in (17),

$$C_T = (1 - \mu_j)[TC_S + C_t(\pi_0 Q_F + \pi_1 Q_D)] \quad (17)$$

where, C_T is the Total Energy, μ_j is the sleeping rate, T is the number of observation samples, C_S is the sensing energy, C_t is the transmitting energy, Q_F is the false alarm probability, Q_D is the detection probability. Since μ, *Cs*, and *Ct* are the same among the sensors.

Energy-saving ratio

For the longer distance transmission between the node and the fusion center, the energy is set as *Eh*; for the shorter distance between node and fusion center, the energy is set as *El*. Hence, the energy-saving ratio is given in (18),

$$\eta_E = \frac{N \times E_h - [(K-1) \times E_l + E_h}{N \times E_h} \quad (18)$$

where E_h is the maximum energy, E_l is the minimum energy, N is the total number of nodes, K is the expectation of nodes through which decision message can be delivered during a sensing period.

Report time-saving ratio

Each node transmits its nearby choice at a particular time slot *Ts*; hence, the time cost for reporting in the cognitive wireless sensor network is *Tc=N×Ts*. Accordingly, the time-saving report ratio can be derived by (19),

$$\eta_T = \frac{N \times T_s - K}{N \times T_s} \quad (19)$$

Where Ts is each node transmits its own local decision at a particular time slot, K is the expectation of nodes through which decision message can be delivered during a sensing period.

Probability of Miss Detection

Miss detection only happens when all nodes in cognitive wireless sensor network missed the primary user signal in a sensing period, the average probability of miss detection for cooperative spectrum sensing is denoted by equation (20),

$$Q_m = \prod_{i=1}^{N} P_{m,i} \quad (20)$$

where $P_{m,i}$ is the probability of miss detection. The probability of miss detection for cooperative spectrum sensing is given by (21),

$$P_{m,i} = 1 - P_{d,i} \quad (21)$$

where $P_{d,i}$ is the detection probability. The detection probability is defined in equation (22),

$$P_{dj} = P(E_j > \epsilon | H_1) Q_{\delta f_s}(\sqrt{2\gamma_j}, \sqrt{\varepsilon}) \quad (22)$$

where, $Q_m(a,b)$ is the generalized Marcum Q-function, γ_j is the primary-user SNR in the *j*th sensor under the hypothesis H_1.

III. RESULTS AND DISCUSSIONS

SIMULATION STANDARD

The simulation parameters are based on IEEE 802.15.4 standard, and the specification is based on a case study with IEEE 802.15.4 /ZigBee radios. For the receiver sensitivity of -90dbm, the sensing energy and transmission energy is provided as, Sensing energy Cs=190nJ, Transmission energy Ct= 80nJ, α=0.1, β=0.9, SNR=10dB, Number of Observation Samples T= 5.

COOPERATIVE SPECTRUM SENSING CONFIGURATION

The environment of cooperative spectrum sensing is formed, as shown in Fig 3. A cognitive sensor network with 50 sensor nodes is deployed randomly in the square field of 200 m.

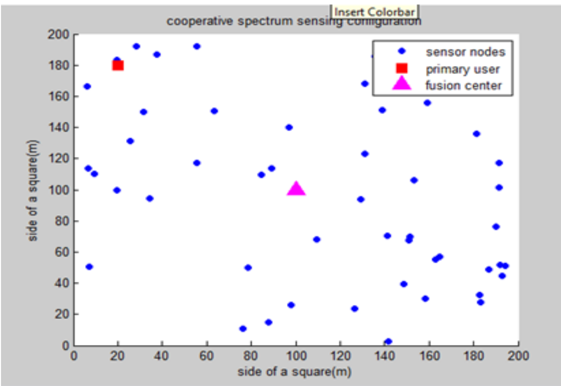

Fig 3 Cooperative Spectrum sensing configuration

The total energy consumption is calculated for a set of P-selected nodes out of N nodes using the equation (4). For the P selected nodes, the total energy is calculated for various environments by varying the path loss exponent value such as α=2 for the free-space environment, α=2.8 for the urban area, α= 3.6 for the suburban area and rural environment, and α=4 for the relatively lossy environment. For a total of 50 nodes, the energy value is calculated, and the average energy consumption for the various environment is calculated and shown in Fig.4It is observed that average energy consumption is calculated for 11 selected nodes out of 50 total nodes for various environments such as free space environment, urban area, suburban and rural area, and the relatively lossy environment by varying the path loss exponent.

```
Total nodes      50

Selected nodes     11

average energy consumption in Joules
alpha=2     5.5435e-07

alpha=2.8     1.0202e-06

alpha=3.6     2.3213e-06

alpha=4     5.1939e-06
```

Fig.4 Average energy consumption for various environments

The reduced energy consumption is obtained for the free-space environment is about 554 nJ, and for an urban area, the average energy consumed is about 1020 nJ; for the suburban area and relatively lossy environment, the average energy consumed is about 2313 nJ and 5193 nJ, respectively. Average energy consumption for 11 selected nodes out of 50 total nodes for various environments such as free space environment, urban area, suburban and rural area, and the relatively lossy environment by varying the path loss exponent are plotted as shown in Fig.5.

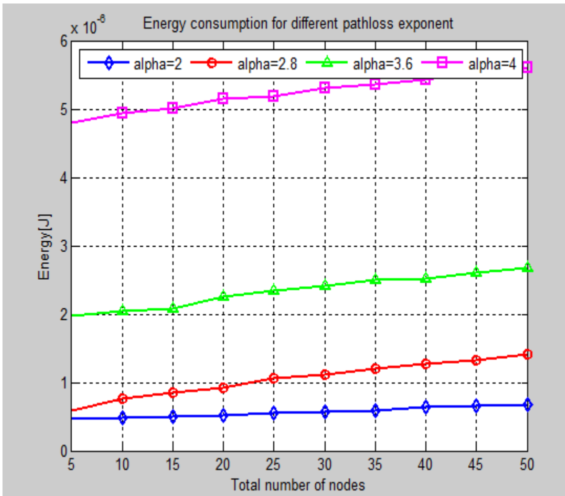

Fig.5 Average energy consumption

It is observed that the free space environment has reduced energy consumption compared to other environments. Relatively loss energy consumes more energy due to the higher path loss exponent value. Average energy consumption for different selected nodes is calculated as listed in Table1. The selected nodes are based on the minimal distance from the primary user and nodes and maximum weighted nodes. The number of nodes in the distance less than or equal to one-fourth of diagonal is allocated with the maximum weight of 4 is considered to be the selected nodes

COMBINED CENSORING AND SLEEPING SCHEME

The false alarm probability for the OR rule is calculated using the equation (13). This probability protects the transmission of the primary user from the interference produced by the secondary user. The detection probability for the OR rule is calculated using the equation (13)

Detection performance for OR fusion rule is plotted for 50 nodes, as shown in Fig 6. It shows that the false alarm probability rises as N rises from 5 to 50 nodes, and the detection probability is exponentially fallen as N rises from 5 to 50 nodes.

Detection performance for AND fusion rule is plotted for 50 nodes, as shown in Fig 7. It shows that the false alarm probability rises as N rises from 5 to 50 nodes and the detection probability is exponentially grows as N rises from 5 to 50 nodes. The censoring rate and sleeping rate is obtained by using the equation (12)

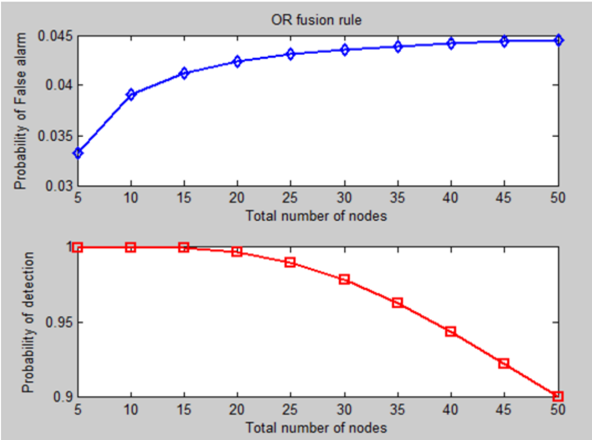

Fig 6 Detection performance for OR fusion rule

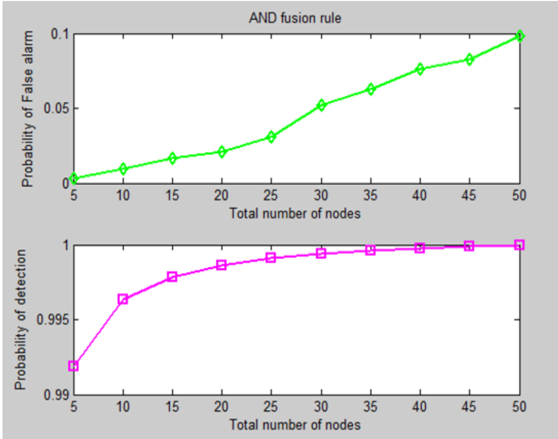

Fig. 7 Detection performance for AND fusion rule

Table 1 Average Energy Consumption for different selected nodes

Selected Nodes	Average Energy Consumption (Joules)			
	α=2	α=2.8	α=3.6	α=4
5	$3.7969x10^{-07}$	$6.5515x10^{-07}$	$1.4753x10^{-06}$	$3.3166x10^{-06}$
6	$4.1794x10^{-07}$	$7.1942x10^{-07}$	$1.6178x10^{-06}$	$3.5870x10^{-06}$
7	$4.2226x10^{-07}$	$7.3111x10^{-07}$	$1.7425x10^{-06}$	$3.8914x10^{-06}$
8	$4.7593x10^{-07}$	$7.9569x10^{-07}$	$1.8868x10^{-06}$	$4.1851x10^{-06}$
9	$5.1648x10^{-07}$	$8.6626x10^{-07}$	$2.0526x10^{-06}$	$4.5288x10^{-06}$
10	$5.3085x10^{-07}$	$9.0960x10^{-07}$	$2.1058x10^{-06}$	$4.870x10^{-06}$
11	$5.5435x10^{-07}$	$1.0202x10^{-06}$	$2.3213x10^{-06}$	$5.1939x10^{-06}$
12	$6.2469x10^{-07}$	$1.1011x10^{-06}$	$2.4255x10^{-06}$	$5.5558x10^{-06}$
13	$6.6348x10^{-07}$	$1.1374x10^{-06}$	$2.6429x10^{-06}$	$5.7323x10^{-06}$
14	$6.9194x10^{-07}$	$1.2174x10^{-06}$	$2.7079x10^{-06}$	$6.1075x10^{-06}$

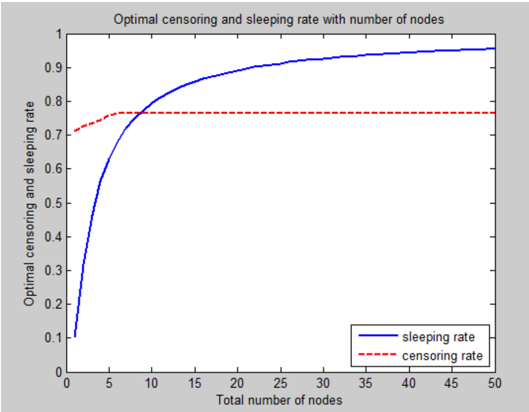

Fig 8 Censoring and sleeping rate

Fig8 shows how the optimal censoring and sleeping rates change concerning the number of nodes for $\alpha=0.1$ and $\beta=0.9$. It infers that as the number of nodes rises, the optimal sleeping rate rises dramatically to maintain a stable energy consumption system. However, the optimal censoring rate steeps after a limited number of nodes. For the combined censoring and sleeping scheme, the total energy consumption is calculated using the equation (17).

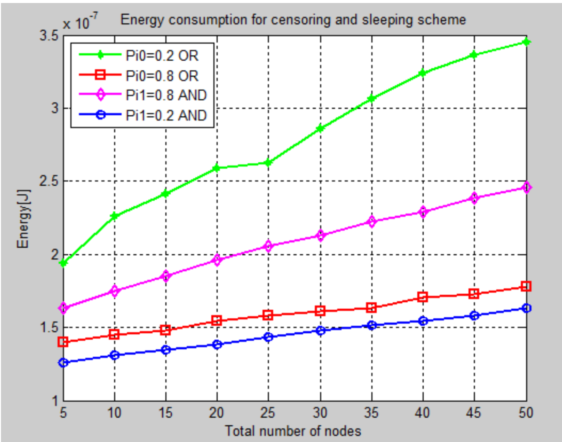

Fig.9 Energy consumption for Censoring and sleeping scheme

Fig.9 shows that the average energy consumption for low values of π AND rule overtakes the OR rule and for high values of π OR rule overtakes the AND rule.

The average energy consumption when $\pi_0 = 0.2$ for OR fusion rule is about 271 nJ, and for AND fusion rule is about 143 nJ. The average energy consumption when $\pi_0 = 0.8$ for OR fusion rule is about 157 nJ and for AND fusion rule is about 203 nJ, The probability of miss detection for AND fusion rule and OR fusion rule is obtained using the following equation (21),

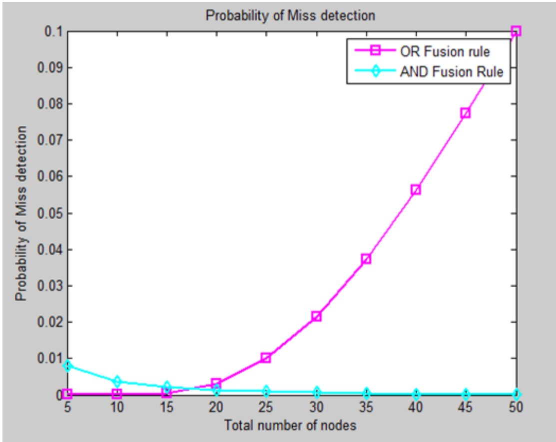

Fig.10 Probability of Miss Detection

In Fig.10 Probability of miss detection is plotted for a total number of nodes using both AND fusion rule and OR fusion rule. It shows that the probability of miss detection using OR fusion rule rises as the total number of nodes rises, and using AND fusion rule falls as the total number of nodes rises. The energy-saving ratio for AND fusion rule and OR fusion rule is calculated using the equation (18).

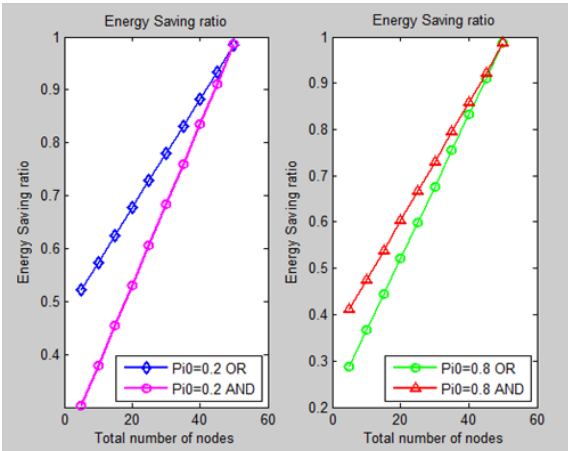

Fig.11 Energy saving ratio

The energy-saving ratio for low values of $\pi=0.2$ AND rule overtakes the OR rule, and for high values of $\pi=0.8$ OR rule overtakes the AND rule as shown in Fig 11. The average energy saving ratio for the 0.2 probability coefficient is 0.7333 for OR fusion rule and 0.6145 for AND fusion rule. The average saving ratio for the 0.8 probability coefficient is 0.6071 for OR fusion rule and 0.6732 for AND fusion rule. It clears that the average energy saving ratio for a lower value of probability coefficient as 0.2, AND rule outpaces OR rule and for a higher value of probability coefficient as 0.8, OR rule outperforms AND rule. The false alarm probability is calculated by using equation (13) for OR fusion rule and by equation (15) for AND fusion rule.

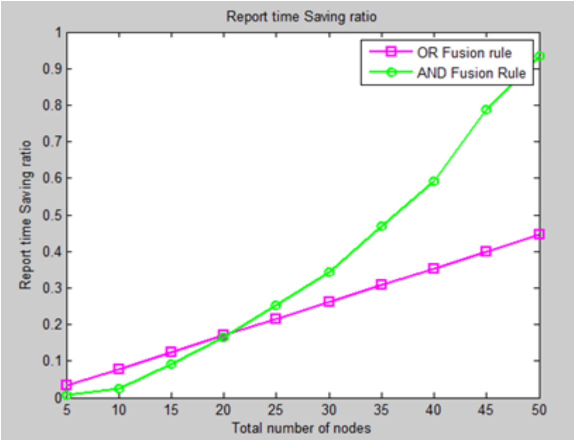

Fig.12 Report time-saving Ratio

The calculated values of the report time-saving ratio for AND fusion rule and OR fusion rule are plotted as shown in Fig.12. As the false alarm probability increases, the time-saving report ratio also gradually increases; it is plotted for a total number of nodes.

Table 2 Comparison of Energy consumption

Combined Censoring and Sleeping Scheme			
π_0= 0.2 OR	***π_0= 0.8 OR***	***π_0= 0.2 AND***	***π_0= 0.8 AND***
271 nJ	157 nJ	143 nJ	203 nJ
Knapsack Based Energy Efficient Node Selection Scheme			
Selected Nodes		***Energy***	
5		379 nJ	
14		690 nJ	

The simulation results of combined censoring and sleeping scheme and knapsack-based energy-efficient node selection scheme are compared as listed in Table 2. It shows that the KEENSS provides reduced energy consumption for a minimum number of selected nodes. KEENSS is compared with censoring and sleeping scheme, censoring and sleeping scheme provides reduced energy consumption.

CONCLUSION

This work will reduce energy consumption in cooperative spectrum sensing by various methods such as knapsack-based energy-efficient node selection schemes and censoring and sleeping schemes. The network energy consumption is reduced subject to a limit on the detection probability, and false alarms are derived for AND rule and OR rule and by considering censoring and sleeping rate. As energy consumption for both KEENSS and combined censoring and sleeping is calculated. KEENSS provides reduced energy consumption for a minimum number of selected nodes; for 5 selected nodes, the energy consumed is about 379 nJ and for 14 selected nodes is about 690 nJ. Censoring and sleeping scheme provides reduced energy consumption compared to KEENSS. In censoring and sleeping scheme, for lower values of prior probability coefficients as 0.2, AND fusion rule has reduced energy consumption for about 143nJ, and higher values of prior probability coefficients as 0.8, OR fusion rule has reduced energy consumption for about 157nJ.

The performance metrics such as the probability of miss detection, Energy Saving Ratio (ESR), and Report Time Saving Ratio (RTSR) are calculated. The performance metrics result shows that AND rule outperforms OR rule in the probability of miss detection and report time-saving ratio. The average report time-saving ratio for OR fusion rule is 0.2207 and for AND fusion rule is 0.3289. Energy Saving Ratio (ESR) is calculated based on energy consumption, which depends on the probability coefficient, which varies with higher and lower values. The average energy saving ratio for the 0.2 probability coefficient is 0.7333 for OR fusion rule and 0.6145 for AND fusion rule. The average energy saving ratio for the 0.8 probability coefficient is 0.6071 for OR fusion rule and 0.6732 for AND fusion rule. It clears that the average energy saving ratio for a lower value of probability coefficient as 0.2, AND rule outperforms OR rule, and for a higher value of probability coefficient as 0.8, OR rule outperforms AND rule.

The simulation result shows that reduced energy consumption is obtained using combined censoring and sleeping scheme. The simulation result of performance metrics shows that AND rule outperforms OR rule in the probability of miss detection and Report time-saving ratio. The energy-saving ratio depends on the probability coefficient, which in turn varies with higher and lower values. For a lower value of probability coefficient AND rule outperforms OR rule and for a higher value of probability coefficient OR rule outperforms AND rule.

REFERENCES

[1] Hock Guan Goh, Kae Hsiang Kwong, and Ivan AndonovicandSoung-YueLiew, "*The implementation of the cognitive wireless Sensor network using rule-based and supervised approaches"* in IEEE International Conference on Frontiers of Communications, Networks and Applications, November 2014, pp. 1-6

[2] Md. AlimulHaque, Md. Faizanuddin, N. K. Singh, "*A Study of Cognitive Wireless Sensor Networks: Taxonomy of Attacks and Countermeasures*" in World Applied Programming, Vol (2), Issue (11), November 2012. 477-484, ISSN: 2222-2510.

[3] Gayathri Vijay, Elyes Ben Ali Bdiraand Mohamed Ibnkahla, "*Cognition in Wireless Sensor Networks: A Perspective*," IEEE Sensors Journal, Vol. 11, No. 3, March 2011.

[4] S. Men, Y. Zhou, X. Sun, and Z. Zhou, "*A Cooperative Spectrum Sensing Scheme in Wireless Cognitive Sensor Network,"* Proceedings of the IET International Conference on Communication Technology and Application (ICCTA), 2011, pp. 577-581.

[5] Amir SepasiZahmati, SattarHussain, Xavier Fernando, Ali Grami, "*Cognitive Wireless Sensor networks: Emerging Topics and Recent Challenges*," IEEE Toronto International Conference, 2009

[6] Andreas Willig, "Recent and Emerging Topics in Wireless Industrial Communications: A Selection," IEEE Transactions on Industrial Informatics, vol. 4, no. 2, May 2008.

[7] Maryam Monemian, Mehdi Mahdavi, and Mohammad JavadOmidi, "*Optimum Sensor Selection Based on Energy Constraints in Cooperative Spectrum Sensing for Cognitive Radio Sensor Networks*" IEEE sensors journal, vol. 16, no. 6, March 15, 2016.

[8] D. Mercedes, M. Plata, and A. G. A. Reatiga, "*Evaluation of energy detection for spectrum sensing based on the dynamic selection of detection threshold*," Elsevier Procedia Engineering, International Meeting of Electrical Engineering Research 2012.Volume 35, 2012, pp. 135–143.

[9] Nan Zhaot, F. Richard Yu, Hongjian Sun, and ArumugamNallanathan, "*An Energy-Efficient Cooperative Spectrum Sensing Scheme for Cognitive Radio Networks*," IEEE Global Communications Conference (GLOBECOM), December 2012, pp.3600 - 3604, ISSN: 1930-529X.

[10] S. Maleki, A. Pandharipande, and G. Leus, "*Energy-efficient distributed spectrum sensing for cognitive sensor networks,"* IEEE Sensors Journal., vol. 11, no. 3, pp. 565–573, Mar. 2011.

[11] SamanAtapattu, ChinthaTellambura, Hai Jiang, *"Energy Detection Based Cooperative Spectrum Sensing in Cognitive Radio Networks*" in IEEE Transactions on wireless communication, vol. 10, No. 4, April 2011.

[12] T. Yucek and H. Arslan, "*A survey of spectrum sensing algorithms for cognitive radio applications*," IEEE communications surveys & tutorials, vol. 11, no. 1, first quarter 2009vol. 11, no. 1, pp. 116–130, 2009.

[13] W. Zhang, R. K. Mallik, and K. B. Letaief, "*Cooperative spectrum sensing optimization in cognitive radio networks*," IEEE Transactions on Wireless Communication, vol. 8, no. 12, pp. 5761–5766, Dec. 2009.

[14] A. Ghasemi and S. Sousa, "*Spectrum sensing in cognitive radio networks: Requirements, challenges, and design trade-offs,*" IEEE Communication Magazine, vol. 46, no. 4, pp. 32–39, Apr. 2008.14]NavdeepKaurKapoor, ShikhareshMajumdar, and BiswajitNandy, "Techniques for Allocation of Sensors in Shared Wireless Sensor Networks," Journal of Networks, vol. 10, no. 1, January 2015.

[15] N.u. Hasan, W. Ejaz, S. Lee, H.S. Kim, "*Knapsack-based energy-efficient node selection scheme for cooperative spectrum sensing in cognitive radio sensor networks*" IET Communications, 2012, Volume:6, Issue: 17, pp.2998 – 3005, ISSN:1751-8628.

[16] Zaheer Khan, JanneLehtomäki, Kenta Umebayashi, and Johanna Vartiainen, "*On the Selection of the Best Detection Performance Sensors for Cognitive Radio Networks*" IEEE signal processing letters, vol. 17, no. 4, April 2010.

[17] Manish Arora M. Syamala Devi, "*Weight Based Funds Allocation Algorithm,"* IEEE International Advance Computing Conference, March 2009, pp. 413 – 417.

[18] Edward Peh and Ying-Chang Liang, "*Optimization for Cooperative Sensing in Cognitive Radio Networks*," IEEE wireless communications and networking conference, 2007, pp. 27-32, ISSN: 1525 -3511.

[19] SinaMaleki, Geert Leus, SymeonChatzinotas, and Bjorn Ottersten, "*To AND or To OR: ON Energy-Efficient Distributed Spectrum Sensing with Combined Censoring and Sleeping*" IEEE transactions on wireless communications, vol. 14, no. 8, August 2015.

[20] S. Maleki, S.P. Chepuri and G.Leus, "*Optimization of hard fusion-based spectrum sensing for energy-constrained cognitive radio networks*," Physical communication, vol.9, pp. 193-198, December 2013.

[21] Yunfei Chen, Josef A. Nossek, Amine Mezghani, "*Circuit Aware Cognitive Radios for Energy-Efficient Communication*s" IEEE wireless communications letters, vol.2, no.3, June 2013.

[22] Geert Leus, Rocio Arroyo Valles, SinaMaleki, "*Energy-Efficient Spectrum Sensing for Cognitive Sensor Networks*," IEEE Workshop on Signal Processing Advances in Wireless Communications, June 2013, pp. 155-159, ISSN: 1948-3244.

[23] Stephen Wang, Yue Wang, Justin P. Coon, and Angela Doufexi, "*Energy-efficient Spectrum Sensing and Access for Cognitive Radio Networks,"* IEEE transactions on vehicular technology, vol.61, no.2, February 2012.

[24] WeixiaZou, Wenshuo Zhang, Zheng Zhou, Xiaojun Huang, *"Chain Based OR Rule Cooperative Spectrum Sensing Scheme in Cognitive Sensing Network*s "IEEE international symposium on communications and information technologies, October 2010, pp. 1191-1195.

[25] *AshishPandharipande, SinaMaleki, and Geert Leus, "Energy-efficient spectrum sensing for cognitive sensor networks", IEEE conference on Industrial Electronics, November 2009, pp.2642 - 2646, ISSN: 1553-572X.*

[26] G.Prema, D.Narmatha, "*Performance of energy aware cooperative spectrum sensing algorithms in cognitive wireless sensor network"* International conference on Green engineering and Technologies, 2016 IEEE.

[27] A. Maizate, S. Aouad *"EECDC: An energy Efficient and Coverage-Aware Distributed Clustering Protocol for Wireless Sensor Networks"* International Journal of Engineering Trends and Technology 62.1 (2018): 10-14.