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CLUSTERED HEED BASED DATA TRANSFER STRATEGY FOR COGNITIVE RADIO SENSOR NETWORKS

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ABSTRACT

The paper develops a data transfer mechanism for cognitive radio sensor networks (CRSN) with a view to ensure an increased throughput in a mobile environment. It formulates the theory on the principles of a HEED based methodology in a clustered framework. The philosophy orients to utilize the spectrum effectively through the guidelines of the cognitive radio technology and spring up with measures to improve the performance indices. It augurs to compress the data using Lempel-Ziv-Welsh algorithm (LZW) in an attempt to assuage a smaller bandwidth for the information to reach the destination. The steps encircle a process of aggregation to avoid the transmission of redundant data and further forge to minimize the bandwidth requirements. The NS2 simulation results measured in terms of indices exhibit the merits of the proposed approach over similar other routing methods that include LEACH and AODV and claim its suitability for use in the real world applications.

Keywords: data transfer, clustering, LZW compression, aggregation, throughput.

INTRODUCTION

A wireless sensor network (WSN) consists of a large number of densely deployed sensor nodes with a purpose to observe a wide variety of ambient conditions that include temperature, humidity, vehicular movement, lighting conditions, pressure and the presence or absence of certain kinds of objects [1]. The key operational feature relates to its overcrowded nature and eventually may end up in degrading the performance of the network.

The statistical allocation of the frequency spectrum enables the secondary users (SUs) to access the radio spectrum as and when the primary users (PUs) do not occupy their specified band [2]. Basically each cognitive radio user in the network determines the portion of the available spectrum, selects the best available channel, coordinates the access to this channel with other users and finally vacates the channel in the event of a licensed user being detected.

A WSN equipped with a cognitive radio constitutes a cognitive radio sensor network (CRSN) arbitrates as a distributed network of wireless cognitive radio sensor nodes that sense event signals and collaboratively communicate their readings dynamically over available spectrum bands in a multi-hop fashion to ultimately satisfy the application-specific requirements [3].

Depending on the spectrum availability, the sensor nodes transmit their readings in an opportunistic manner to their next hop cognitive radio sensor nodes, and ultimately to the sink. It poses a great challenge to adopt the CR principle for sensing the underutilized spectrum through the use of the existing protocols. It becomes essential to designate a common channel for the exchange of various control data, such as spectrum sensing results, spectrum allocation data, neighbour discovery and maintenance information. There exists a strong possibility for finding a common channel in a certain restricted locality due to the availability of spatial correlation of the channel.

Therefore cluster-based network architecture fosters to be an appropriate choice for the effective operation of dynamic spectrum management in CRSN. The operation demands the cluster-heads (CHs) to handle additional tasks such as the collection and dissemination of spectrum availability information, and the local bargaining of spectrum. The scope invites new cluster-head selection and cluster formation algorithms for CRSN which jointly consider the inherent resource constraints as well as the challenges and requirements of opportunistic access in CRSN.

The three challenges involved in cognitive routing orient to spectrum awareness, setting up of quality routes and route maintenance. The spectrum awareness belongs to two classes in the sense the first be-hives the full spectral knowledge and the second portrays the local spectral knowledge. The advancements in software defined radio (SDR) CR network can open up new and unexplored service possibilities to provide a wide range of communication applications [4].

Hierarchical based routing appears to be in place ever since data transfer gathered significance and became an imminent need. The reactive source based routing protocol suitable for the CR networks revolve around a probabilistic based novel approach when used over a channel. The Dijikstra like algorithm stops computing once the total capacity falls greater than the demand or else when the destination becomes unreachable. The tree based routing appears to be a centralized routing with a single network entity called the base station which uses global and local decisions schemes for the route calculation [5].

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The clustering techniques offer a saving in energy and attempt to imbibe improved scalability. The clustering approach extends the lifetime of a cognitive network and tries to maintain a balance of the energy consumption among the cognitive radio users [6]. The clustering analysis refers to an iterative process of knowledge discovery or interactive multi-objective optimization that involves trial and failure. The appropriate clustering algorithms and parameter settings depend on the individual data set and intended use of results. It often necessitates modifying the pre-processing of the data and the model parameters until the result achieves the desired properties [7].

The growth mainly depends on the available frequency spectrum in order that the prime radio frequency spectrum (less than 3 GHZ) stands for the assigned licensed users and invites new wireless services to support the overpopulated license free ISM bands above 3GHZ. The reports evince that 90% of the prime radio spectrum augurs to be underutilized and Federal Communications Commission (FCC) introduces a concept for dynamically allocating a spectrum to ensure its full utility.

The theory of Modified Discrete Cosine Transform(MDCT)enlivens a way for compressing the audio signal which allows saving the bandwidth and enjoys reduced power consumption[8].In order to enhance energy efficiency the Hybrid Advanced Distributed and Centralized(HADCC) divides the entire region into multiple sub-iterations called the cluster head selection phase(CHSP),member association phase(MAP) and the data communication phase(DCP).The Bandwidth Efficient Heterogeneity aware Cluster based Data Aggregation (BHCDA) algorithm incites to improve the bandwidth with decreased energy consumption[9].

The Slepian wolf algorithm has been used for reducing the bandwidth and implemented with multi path techniques [10]. The Highest Rate based Multi-cast algorithm (HRM) and Maximum Good put based Multi-cast algorithm (MGM) has been extricated for increasing the throughput in non-real-time applications [11]. The PUMA protocol has been designed to attain a higher packet delivery ratio, lower routing overhead, higher throughput and better packet delivery ratio when compared to Multicast Adhoc On-demand Distance Vector (MAODV) and On-demand Multicast Routing Protocol (ODMRP) in MANET [12].

The radon transform has been incorporated to attain a higher throughput where nodes occupy spatially distributed sparse fields [13]. The efficient resource allocation has been a step for effective use of bandwidth and the elements of resource allocation include power, relay selection, scheduling, delay, routing, QOS and fairness and spectrum allocation [14].

The Bandwidth -Power product metric has been defined for optimizing the bandwidth in comparison to the power metrics at the expense of slight increase in energy consumption [15].

Problem description

The primary effort owes to evolve a strategy for effective transfer of data from a prioritized source to a preferred destination in Cognitive radio sensor networks (CRSN). It beholds to incorporate the benefits of clustering techniques on suitable routing media through the theory of cognitive radio model. The formulation extends to entire stage of compression and LZW based aggregation for facilitating the minimum use of bandwidth. The procedure examines the viability of HEED, LEACH and AODV methods for routing the packets on a NS2 simulator (Network Simulator) Platform.

SYSTEM MODEL

The cognitive radio sensor network fosters to be a novel approach for non-licensed users to use licensed bands opportunistically in the sense if the primary user does not occupy the spectrum, the secondary user can avail the slot to transfer the data. The process of clustering consists of the selection of node with highest energy as the CH and forming the cluster with the remaining nodes as associates. However the density of clustering generates redundant data which increases the communication load and avails the theory of aggregation to overcome the drawback.

The nodes in the cognitive radio sensor networks group themselves into clusters through the principles of the chosen routing method and thereafter engages the selection of the cluster heads (CHs) by FCC in order that it facilitates a minimization of the energy associated with the data transmission between a cluster head and the other members in a cluster. The Figure-1 shows the clustered grouping of a cognitive radio network to guide the routing of the packets.

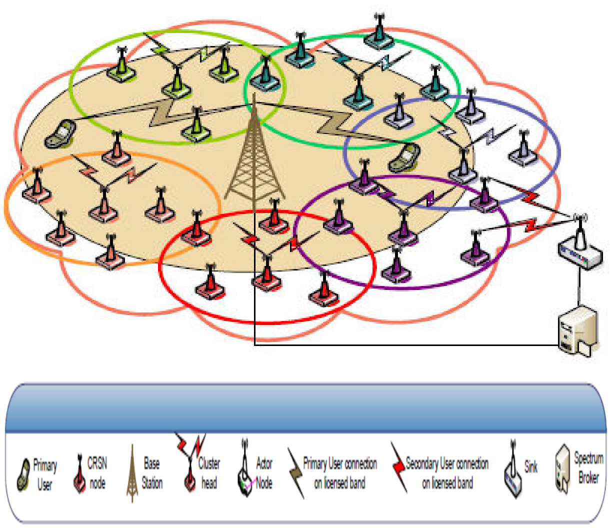

Figure-1. Clustered based network topology for cognitive radio sensor networks.

With the primary user being inactive, the secondary user received signal is written as in Equation (1):

$$y(n) = u(n) \quad (1)$$

With the primary member active, the secondary user received signal is related through Equation (2) as:

$$y(n) = s(n) + u(n) \quad (2)$$

Where s(n) and u(n) respectively denote the signal and the noise.

The total average energy cost can be expressed as seen through Equation (3) as

$$J(\tau_S; P_S) = N\tau_S E_S + NP_3 J_{SW} + SE_t \quad (3)$$

Where E_s and E_t refer to the energy consumption signals for sensing and transmission respectively.

J_{sw} is the energy cost for one channel switching, in the unit of joules;

N is the number of time slots needed for one data packet transmission;

P_3 is the probability of switching to idle channel;
S is the time for one packet data transmission;
τ_S is the sensing time.

In HEED cluster head selection based on combination of node residual energy of each node and a node proximity to neighbours, the probability of becoming the CH is expressed as in Equation (4)

$$P_{CH} = (C \times \frac{E_{RESIDUAL}}{E_{MAX}}) \quad (4)$$

Where $E_{RESIDUAL}$ is the estimated current residual energy, E_{MAX} is the initial energy corresponding to fully charged battery and C is the initial percentage of cluster heads specified by users.

The CH selection probability at a time t is given by Equation (5)

$$P_L(t) = \min((\frac{E_i(t)}{E_{tot}}) \times k, 1) \quad (5)$$

Where E_i is the residual energy of node i,

$$E_{tot} = \sum_{i=1}^{n} E_i(t)$$

K=initial percentage of CH

The compressible aggregation function can be written as in Equation (6)

$$f(C_A) = \Sigma_{i=1}^{k}(X_i) + \frac{1}{M}\Sigma_{j=1}^{M}(Y_j) \quad (6)$$

The total energy consumed by the CH in the aggregation of K bit packets at aggregation is consummated as in Equation (7)

$$E_{CH} = k * E_e\left(\frac{N}{n}\right) + k * E_S d^2 + \left(\left(\frac{N}{n}\right) - 1\right) * k * E_{DA}) \quad (7)$$

Where
E_{DA} = energy consumed in aggregation of data packets
Each cluster contains 'N/n' number of nodes
E_e = energy of transmitter
E_s = energy consumed by node
d^2 = distance of node to cluster head

Proposed approach

The approach consists of three phases that include data compression, data aggregation and the data transmission phase. The Lempel-Ziv -Welch (LZW) correlates a table for particular bit pattern and as the pattern reads, it substitutes the shorter code to reduce the length of data. The decoding program decompresses the file to build the table by itself using the LZW algorithm as it processes the encoded data. The Figures-3 and 4 show the LZW encoding and decoding process respectively. The data can be aggregated to reduce the extra overhead due to the number of transmissions among the packets received from multiple nodes.

The nodes after the process of aggregation transmit the data to the CH and in the event of an intermediate node receiving the data; it allows its passage to the cluster head. However if the CH itself receives the data, it goes on the CHs of the next lower levels and the flowchart in Figure-2 explains the overall process.

The Figures-5, 6 and 7 respectively show the stages involved in LZW-HEED, LZW-LEACH and AODV.

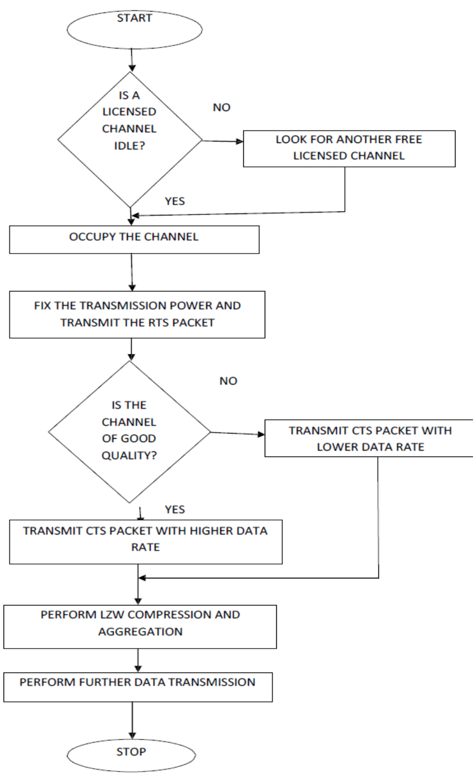

Figure-2. Flowchart for proposed work.

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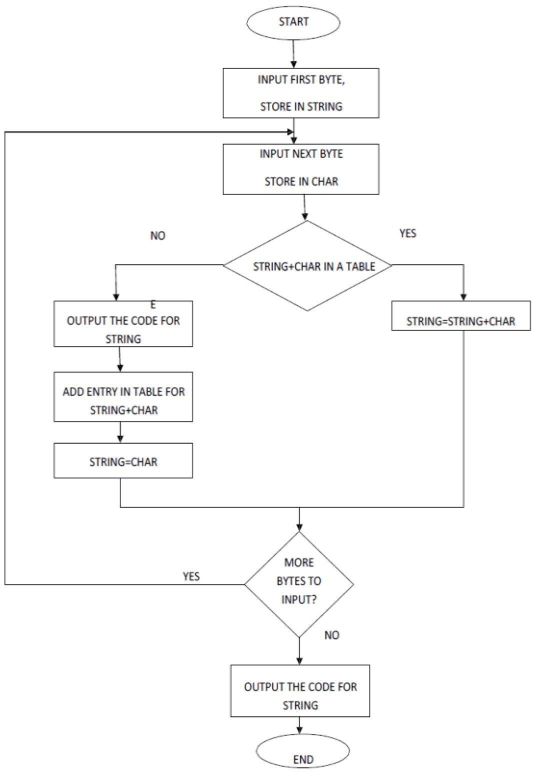

Figure-3. LZW Encoding process.

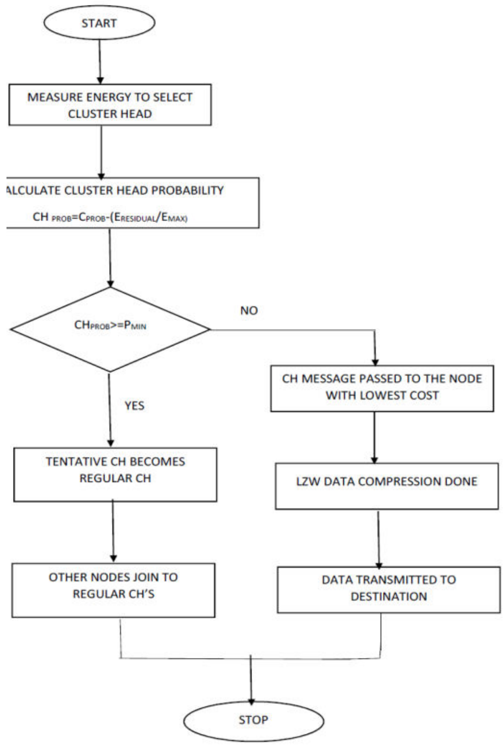

Figure-5. Process of LZW HEED protocol.

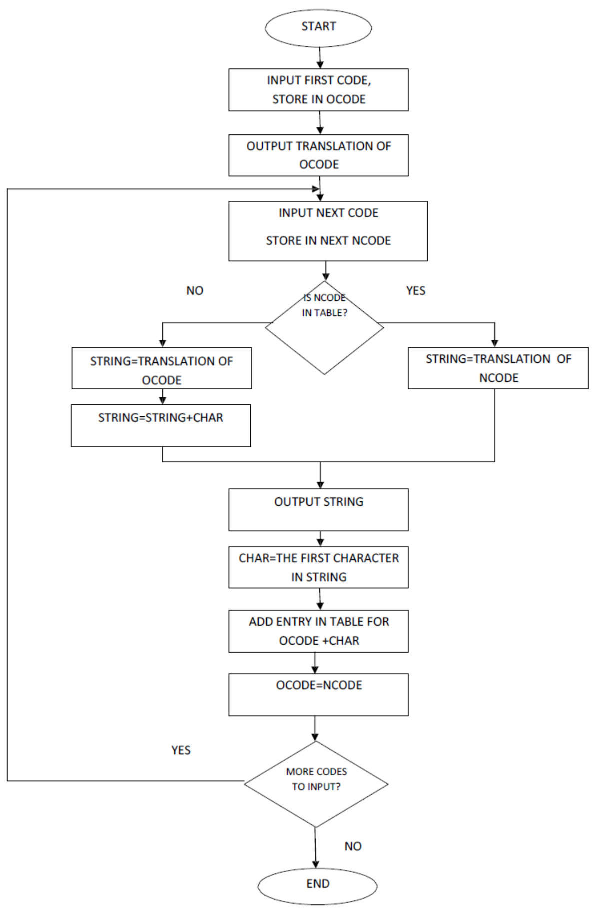

Figure-4. LZW Decoding process.

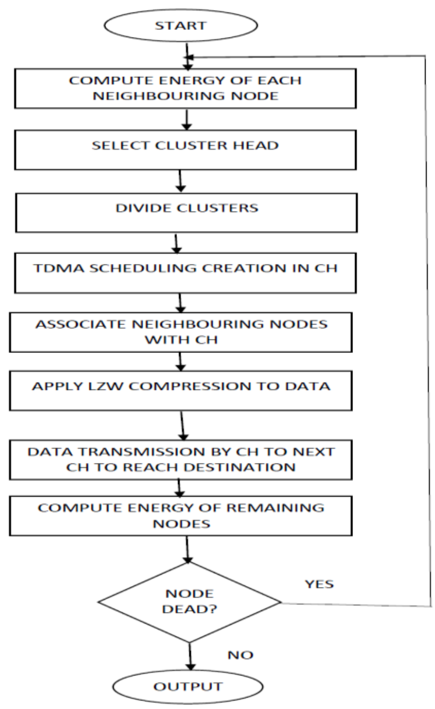

Figure-6. Process of LZW LEACH protocol.

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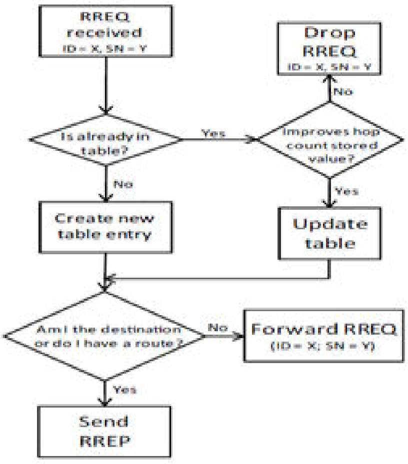

Figure-7. Process of AODV protocol.

SIMULATION RESULTS

The Figures 8 and 9 respectively show the network model in the NS2 platform and the pattern of the flow of the data in the network.

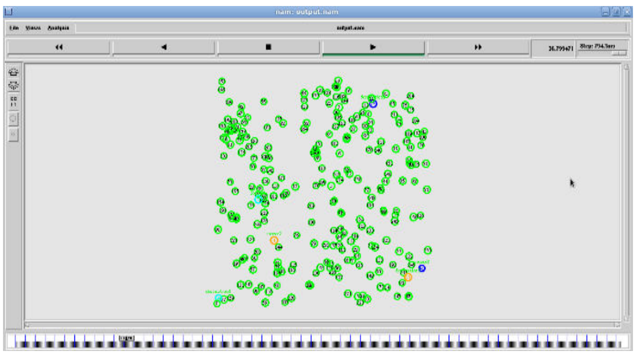

Figure-8. Network model.

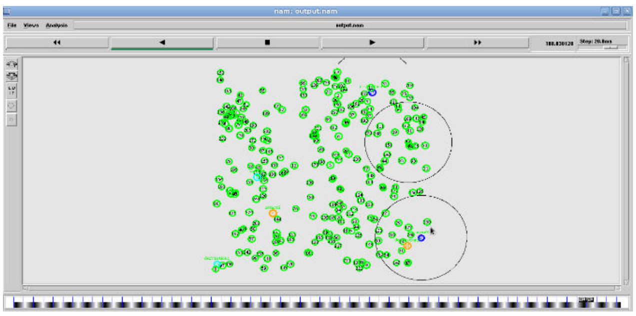

Figure-9. Routing in network.

The design of routing methods attempt to guarantee a higher throughput in cognitive radio sensor networks and the role of cluster based routing benefits the formulation. The methodology investigates the performance of cluster based HEED, LEACH and AODV routing with two hundred and fifty nodes distributed in 1000 m X 1000 m in a cognitive radio network which involves routing between three sources and three destinations. The procedure evaluates using NS2 graphs the performances including packet delivery ratio (PDR), routing overhead, packet loss, routing delay, energy expended, and throughput.

The packet delivery ratio (PDR) of a network is given by Equation (8) as

$$Packet\ Delivery\ Ratio = \left(\frac{Number\ of\ Packets\ Received}{Number\ of\ Packets\ sent}\right) \quad (8)$$

The average end to end delay for routing the packets is given as in Equation (9)

$$D(\tau_S; P_{S)} = N\tau_S + NTP_{WT} \quad (9)$$

Where $P_{WT}$is the probability that the Secondary User waits on the current channel.

The SU requires waiting for τ_s for each frame so that the first part of the formula describes the delay for sensing in N frames. If the SU waits on the current channel with the probability ofτ_S, the time of this kind of delay in N frames turns out to be NTP_{WT}.

The throughput of the network can be written as in Equation (10)

$$Average\ Throughput = \frac{N}{(T_{LAST} - T_{FIRST})} \quad (10)$$

Where N denotes the Number of bits received by destination nodes,

$T_{LAST,}$ the receive time of last packet in network by destination node and

$T_{FIRST,}$ the send time of first packet in network.

The probability that exists i occupied channels and K-i free channels is determined by the traffic density of the primary user and can be expressed as in Equation (11)

$$P_{(K,i)} = (1-\beta)^{K-i}\beta^i \quad (11)$$

Where$\beta = \left(\frac{\alpha_1}{\alpha_1+\alpha_0}\right)$

The probability that the secondary user senses atleast one free channel and allows to access one of them, is given by Equation (12)

$$P_{(K,i<K)} = (1-\beta^K) \quad (12)$$

The throughput of the secondary user can thus be expressed as in Equation (13)

$$R_P^*(K,T) = P(K,i<K)\frac{T-\tau}{T}(1-P_p^s)C \quad (13)$$

The normalized throughput may be expressed as in Equation (14)

$$R_P^*(K,T) = P(K,i<K)\frac{T-\tau}{T}(1-P_p^s) \quad (14)$$

Where T refers to the frame duration. The energy of the network is given by Equation (15)

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$$Average\ energy\ consumption = \frac{(Initial\ energy - Final\ Energy)}{Total\ Number\ of\ Nodes} \quad (15)$$

The Figures 10 to 14 shown through the line graph bring out the merits of HEED in terms of increase in PDR, decrease in overhead and delay, rise in throughput and fall in energy consumption for a range of packet sized transmission of data over the other two routing methods.

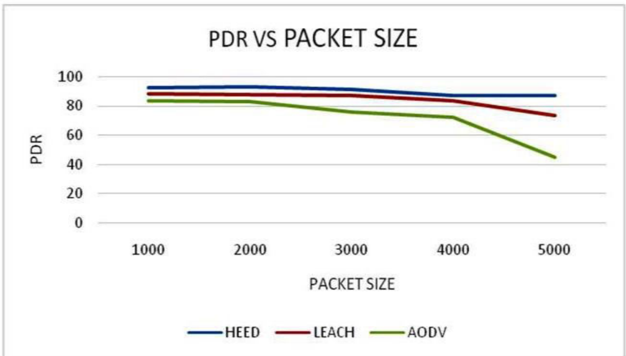

Figure-10. PDR vs Packet size.

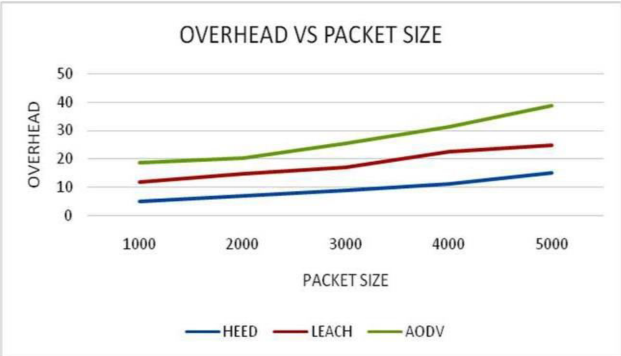

Figure-11. Overhead vs Packet size.

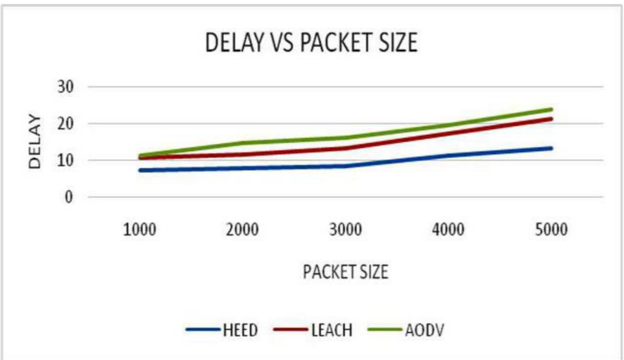

Figure-12. Delay vs Packet size.

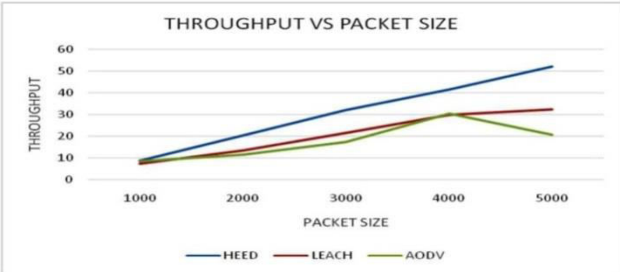

Figure-13. Throughput vs Packet size.

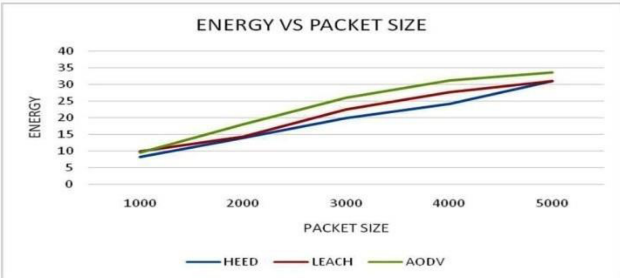

Figure-14 . Energy vs Packet size.

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Table-1. Comparitive performance of PDR for three routing protocols.

Protocol	Packet size	Without compression and Aggregation (Normal routing)	After compression
HEED	1000	92.47	99.47
	2000	92.94	97.68
	3000	91.26	97.01
	4000	87.2	92.37
	5000	87.28	91.79
LEACH	1000	88.18	93.47
	2000	87.57	91.94
	3000	86.95	88.71
	4000	83.29	90.57
	5000	73.22	74.25
AODV	1000	83.67	90.91
	2000	82.85	85.84
	3000	76.17	80.42
	4000	72.23	73.55
	5000	44.78	46.09

Table-2. Comparitive performance of overhead for three routing protocols.

Protocol	Packet size	Without compression and aggregation (Normal routing)	After compression
HEED	1000	5	3.58
	2000	7	4.16
	3000	9	6.21
	4000	11	8.99
	5000	15	12.37
LEACH	1000	11.76	9.76
	2000	14.65	12.15
	3000	16.85	15.85
	4000	22.4	20.85
	5000	24.83	22.83
AODV	1000	18.59	15.59
	2000	20.1	18.1
	3000	25.37	23.37
	4000	31.15	29.15
	5000	38.62	36.62

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Table-3. Comparitive performance of delay for three routing protocols.

Protocol	Packet size	Without compression and aggregation (Normal routing)	After compression
HEED	1000	7.3	4.56
	2000	7.94	5.88
	3000	8.5	7.53
	4000	11.27	9.26
	5000	13.2	12.19
LEACH	1000	10.84	7.4
	2000	11.54	8.47
	3000	13.42	10.41
	4000	17.26	14.42
	5000	21.32	18.32
AODV	1000	11.33	9.14
	2000	14.65	12.6
	3000	16.1	14.04
	4000	19.71	16.7
	5000	23.81	19.79

Table-4. Comparitive performance of throughput for three routing protocols.

Protocol	Packet size	Without compression and aggregation (Normal routing)	After compression
HEED	1000	8.97	11.8
	2000	20.72	23.55
	3000	32.21	35.04
	4000	41.71	44.54
	5000	52.11	54.94
LEACH	1000	7.39	11.03
	2000	13.59	17.23
	3000	21.47	25.11
	4000	29.78	35.16
	5000	32.28	35.92
AODV	1000	8.49	10.49
	2000	11.53	14.53
	3000	17.44	20.44
	4000	30.34	32.34
	5000	20.73	22.73

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Table-5. Comparitive performance of energy for three routing protocols.

Protocol	Packet size	Without compression and aggregation (Normal routing)	After compression
HEED	1000	8.28	5.79
	2000	13.91	11.43
	3000	19.98	17.5
	4000	24.04	21.55
	5000	30.95	28.47
LEACH	1000	9.9	6.91
	2000	14.3	13.32
	3000	22.43	20.43
	4000	27.64	25.89
	5000	31.03	30.03
AODV	1000	9.58	8.58
	2000	18.09	16.09
	3000	26.11	24.11
	4000	31.33	29.33
	5000	33.65	31.66

The Tables 1 to 5 include the performance of the network under normal routing conditions and after the compression of the data in the process of data transfer. The entries establish the significance of the process of compression and further serve to highlight the influence on the effective routing of data.

The readings above elaborate the highest benefits for HEED over the other two routing schemes. The bar charts in Figures-15 through 29 enumerate the similar results after the process of both compressing and aggregating the information.

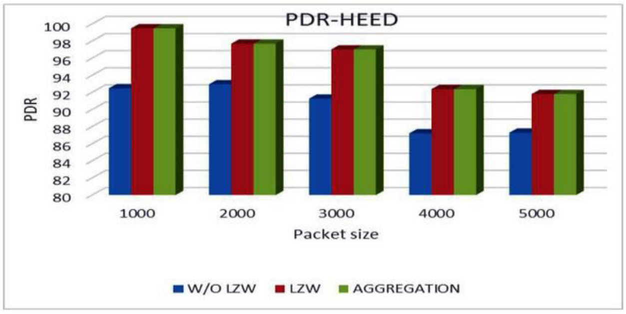

Figure-15. PDR-HEED comparison after compression and aggregation.

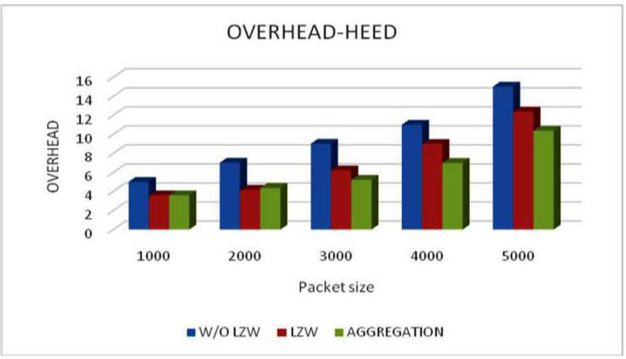

Figure-16. Overhead-HEED comparison after compression and aggregation.

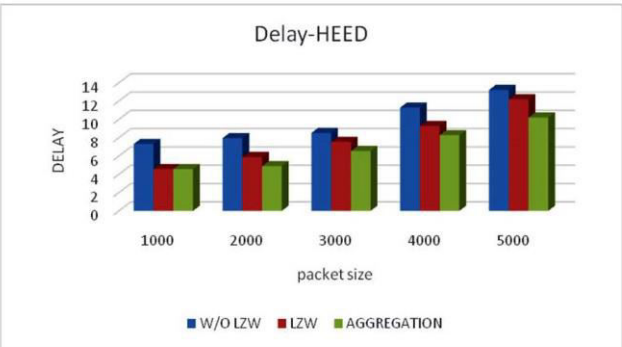

Figure-17. Delay-HEED comparison after compression and aggregation.

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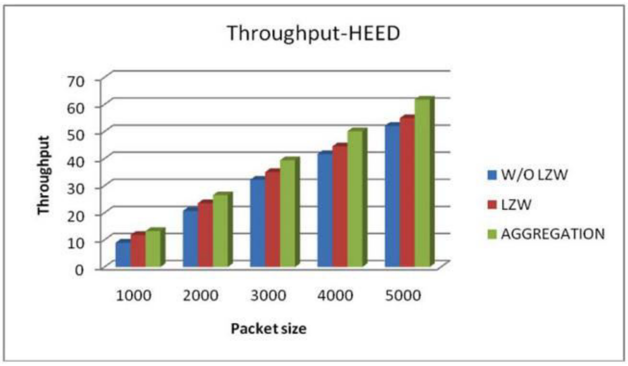

Figure-18. Throughput-HEED comparison after compression and aggregation.

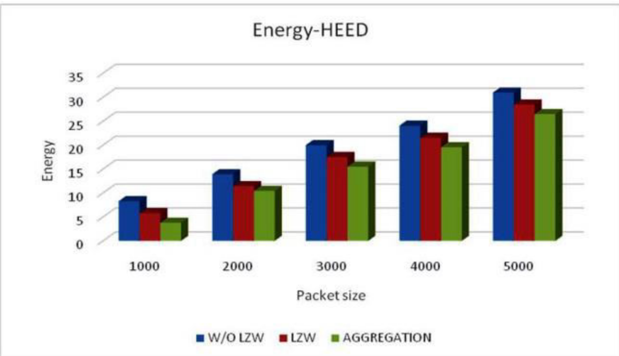

Figure-19. Energy-HEED comparison after compression and aggregation.

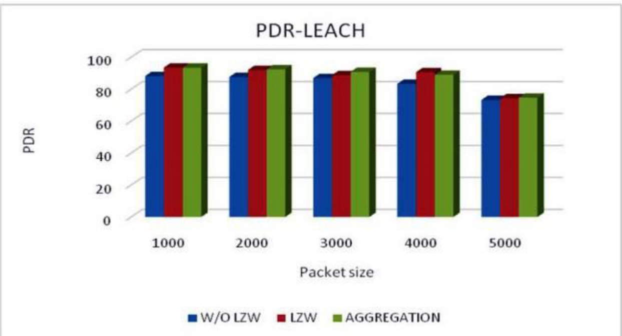

Figure-20. PDR-LEACH comparison after compression and aggregation.

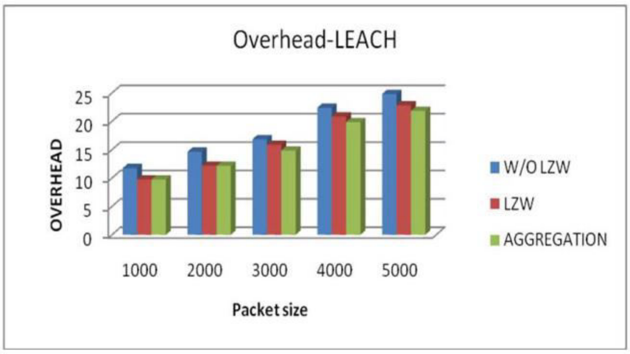

Figure-21. Overhead-LEACH comparison after compression and aggregation.

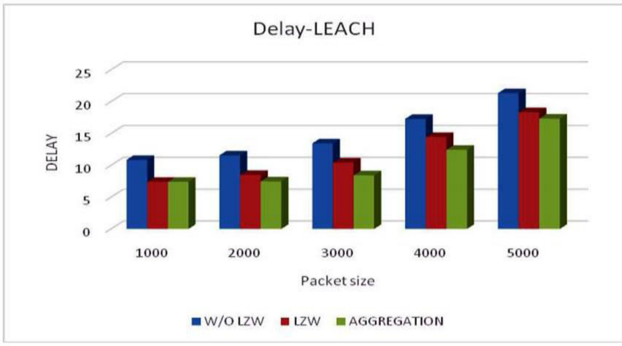

Figure-22. Delay-LEACH comparison after compression and aggregation.

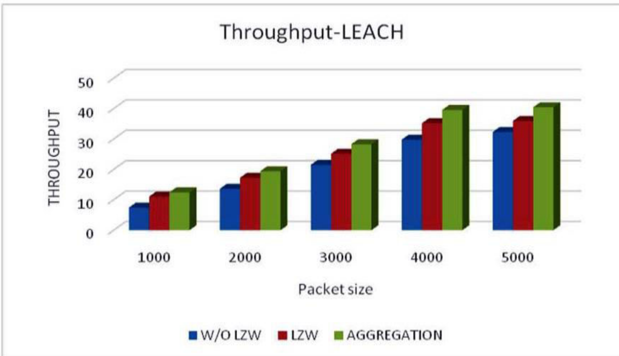

Figure-23. Throughput -LEACH comparison after compression and aggregation.

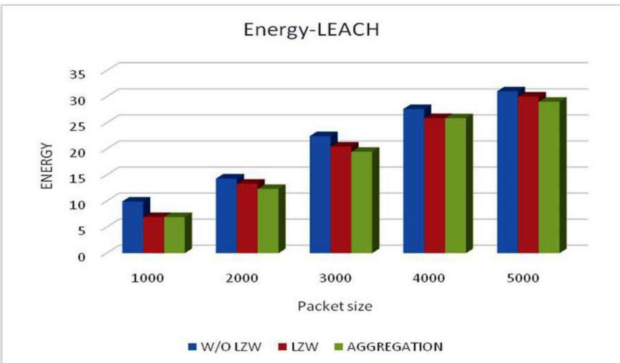

Figure-24. Energy-LEACH comparison after compression and aggregation.

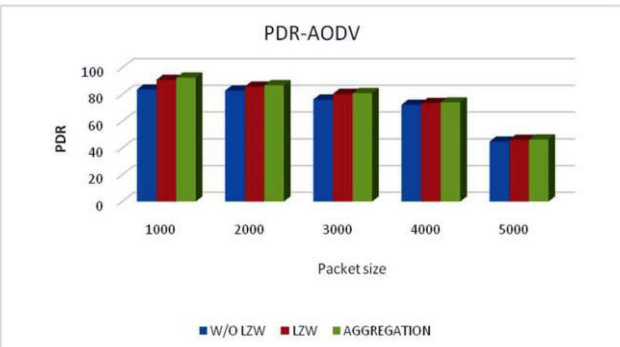

Figure-25. PDR-AODV comparison after compression and aggregation.

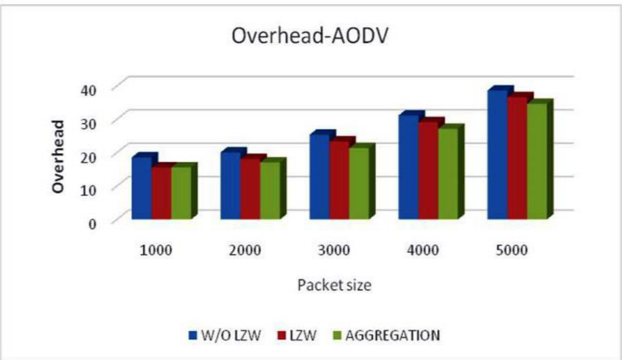

Figure-26. Overhead -AODV comparison after compression and aggregation.

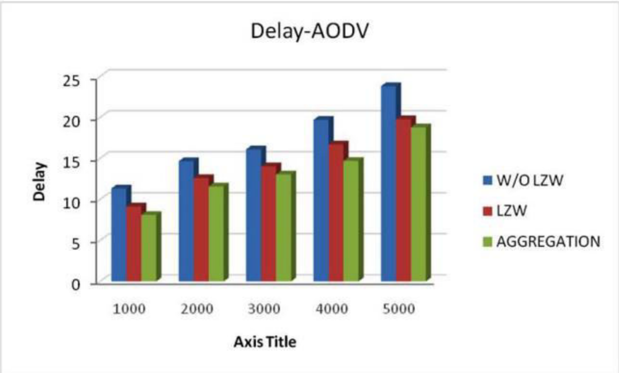

Figure-27. Delay-AODV comparison after compression and aggregation.

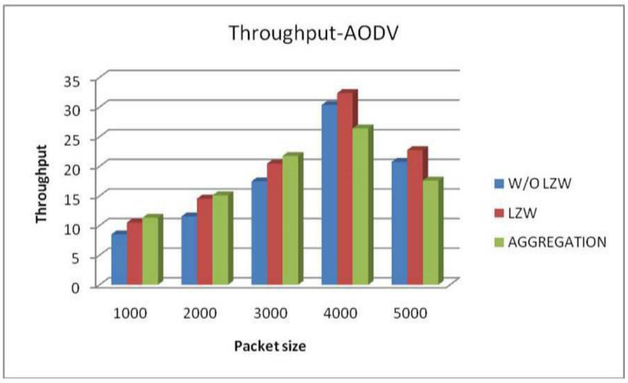

Figure-28. Throughput-AODV comparison after compression and aggregation.

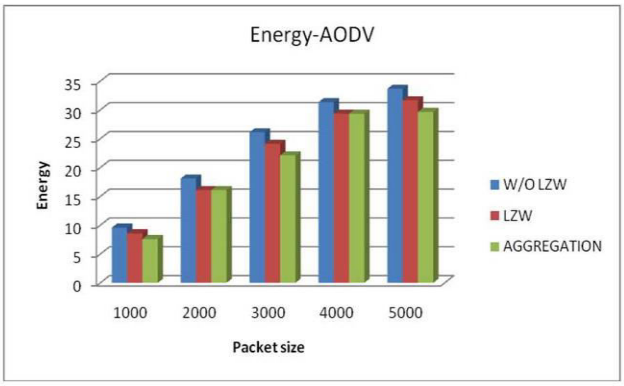

Figure-29. Energy-AODV comparison after compression and aggregation.

CONCLUSIONS

A cluster based strategy has been developed for transferring data among the mobile nodes in a CRSN. The principles of cognitive radio model have been relied in the process of enabling the transfer of packets between the source and destination in the network. The theory of transfer has been articulated using the formulation of HEED, LEACH and AODV routing patterns. The performance has been evaluated through NS2simulation for a 250 node network and the results obtained with routing among the chosen three sources and three destinations nodes. The data have also been aggregated using known methodologies to leave way for allowing a minimum use of bandwidth for the transfer of information. The indices have been seen to offer a higher PDR, increased throughput, reduced delay, overhead packet loss and energy for the cluster based HEED approach over the similar other two methods. The fact that consistent performance has been extricated over varying higher sized packets augurs a space for the proposed scheme in the real world applications.

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