CROSS LAYERED SOLUTION FOR TRAFFIC CONGESTION IN COGINITIVE RADIO SENSOR NETWORK

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ABSTRACT:

The paper develops a cluster based cross layered Hybrid Energy Efficient Distribution (HEED) routing approach with a view to avert traffic congestion in Cognitive Radio Sensor Networks (CRSN). It involves the use of window adaptation and rate-based collision avoidance ideologies in an effort to address link error probability, link breakages, energy depletion, Medium Access Control (MAC) fading and interference. The receiver allows to regulate the window size conferring to the necessities through a process of rate based generic Additive Increase and Additive Decrease (AIAD) and Additive increase and Multiplicative Decrease (AIMD) congestion control schemes. The attempts urge to exploit the available network capacity and bring out the benefits in terms of the parameters that include throughput, energy, packet loss, delay and overhead. The results obtained in the NS2 platform usher in a space for the use of the Dynamic Window Adaptation with Rate Congestion Control technique (DWASRCC) for transferring the data in real world applications.

Keywords: Congestion control, Cross-layer, Cognitive Radio Sensor Networks, HEED, Dynamic Window Adaptation, Rate control techniques.

INTRODUCTION:

The challenges in wireless networking create new trend setting architectures in sensor networks for assuaging component miniaturization and offering improvedquality of service by means of cognitive enabled services with additional capability of dynamic spectrum access. The reconfigurable cognitive radios (CRs) inherit the additional facility of monitoring and sensing in order to distinguish the changes around them [1] for transmitting and receiving the information in different frequency bands. The CRs detect the unused time and provides advanced measures for designing the radios through the use of Intelligent Signal Processing (ISP) with Software Defined Radio (SDR) [2].

The CR based wireless sensor networks operate with multiple channels at each instant of time unlike the case of WSN, where it engages a predefined fixed channel. Each node in the CRSN relates to set of channels whereas in the WSN, the nodes in theentire network foray using the same set of channels[3].The CRSN overcomes the significant drawbacks in the WSN that revolve around the energy consumption and its hardware limitations. However, in many cases the node mobility plays a vital role, which leads to the trade - off between the energy efficiency and the throughput [4] and experience the complexity of the spectrum management.

The clustering techniques appear to improve the energy efficiency of the network and find an extensive implementation in processing the data in the wired networks.It accrues low message overhead, consumes less energy and extends the epoch of the network [5].The HEED based routing considers the nodes to be of similar nature with multiple hops in its networks [6]and fosters the lingering energy as the key parameter to elect itself as a CH. If the lingering energy remains the same in both the nodes, then the next parameter constitutes the degree of the node and the distance between the nodes.

The theory of congestion avoidance in the network layer owes to restrain the delay, collision and reduce the reduce loss in the network [7]. The cross layer dynamic congestion-based window adaptation scheme transmits the packet with the current network condition. It ascertains the window size values dynamically using Spatial Temporal Correlation (STC) and adjusts itself according to the current network.

The philosophy of sharing the bandwidth and optimized route selection along with the Additive Increase and Additive Decrease (AIAD) and Additive increase and Multiplicative Decrease (AIMD)congestion control schemes modelled by Discrete Time Markov chain(DTMC) in terms of the queue length envisage improving the throughput of the network.

Related Works:

The hybrid protocol [8] used in the Mobile Ad-hoc Network (MANET) has been seen to diminish the congestion by adjusting the rate and setting the priority based on the requirements. The prioritization of data has been elicited and the packets transmitted using detour nodes in case two or more nodes attempt to transfer the packets using the shortestpath from the source node. The congestion has been controlled by monitoring the network transmission and the error reduced by using the proactive table -driven strategy.

TheAdaptive Reliable and Congestion Control Routing Protocol (ARCCRP) has been used to reduce the congestion through multipath route selection and by shifting the portion of traffic in the alternate path [9]. It has been implemented with hop by hop technique[10] and the Temporarily Ordered Routing Algorithm (TORA)routing shown to improve the performance parameters of the network.

The method followed by the Differentiated Queuing Service(DQS)for multi-hop wireless network has been the outcome of the joint Quality of Service (QoS) provisioning and a congestion control scheme. The Semi-Transmission Control Protocol(TCP) [Semi-TCP which decouples two functionalities of traditional TCP, i.e., congestion control and reliability control, in order to get rid of the constraint of TCP's congestion window on performance enhancement]has been used for efficient hop by hop congestion control and a fast approximation of the latest parting time evolved to handle the overdue packets. An adaptive acknowledgement (ACK) scheme together with the design of a shared database cross layer architecture for implementation in protocol stack have been the solutions for the stand -up problems[11].

The window boundary has been seen to remain within the surpass hop count of the forward and backward path between the source and destination for setting the limit and an upper bound on bandwidth delay product derived to be 1/5 of the Round -Trip Hop Count (RTHC) of the route[12].

The Cluster Based on Congestion Control (CBCC) has been formulated using scalable and distributed clusters in the MANET for monitoring the congestion level in its localized area to communicate the information through the CHs and indirectly reduces the control overhead [13].The nodes in the cluster have been fostered to communicate its current load and approximate the traffic rate by collecting the load estimates to vary the data transmission rate at the source proactively.

The cross layer Explicit Control Protocol Wireless Interface Mechanism (XCP-Winf) and Rate Control Protocol Wireless Interface Mechanism (RCP-Winf) have been witnessed to exploit the MAC layer information and the link capacity and the bandwidth information obtained by exchanging the RTS-CTS data [14].

The Network Utility Maximization (NUM)model has been used as a rate allocation for cross layer congestion control design [15].The simple rate adjustment algorithms has been laid to entail the congestion avoidance technique [16] [17] and offer the buffer occupancy of network nodes as the congestion detection metric in the transport layer.

TheEvent-to-Sink Reliable Transport (ESRT) [18], Reliable Transport ($RT^{2)}$ [19], congestion Detection and avoidance (CODA)[20]. This strategy simultaneously combines the queue occupancy, forwarding delay, and rate limiting algorithms (Fusion) [21],(siphon) [22]a set of distributedalgorithmsthatsupportvirtualsinkdiscoveryandselection,congestion detection andtraffic redirection in sensor networks (STCP)[23],Delay sensitive transport (DST)[24]and collaborative transport control protocol(CTCP) [25] have been reflected to use thebuffer occupancy as the congestion detection metric. The tunable reliability with congestion control for information transport (TRCCIT) has been used for congestion detection [26] and the node delay engulfed as the congestion detection metric [19][24].

Despite the developments, still the need exists to augur a cross layer congestion control approach with appropriate energy, dynamic window adaptation and rate control mechanism to improve the quality of service.

System Model:

The Fig.1 shows the system architecture, in which there exists N_{SU} Secondary Users and N_{PU} Primary Users arranged in the CRSN. It consists of a number of non-overlapping orthogonal channels $\{Ch \,|Ch_i, i = 1, 2, \ldots, n\}$ with an exclusive ID for each channel. Each node being conscious of its location,includes a single half-duplex CR transceiver to be able to proficientlysense and exploitthe spectrum holes in a dispersed and well-organized way. Two Secondary User (SU) nodes constitute to be a one-hop neighbour if they remain within each other's transmission range. The CRs or SUs coincide with PUs and either speculativelyortentativelyaccess the channels.

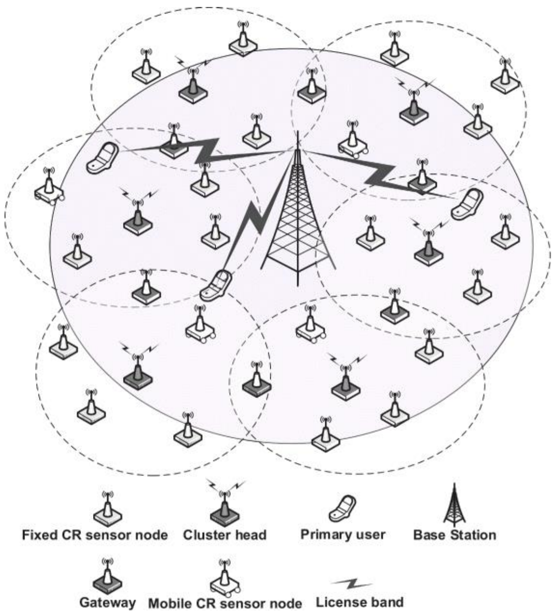

Fig. 1 System Architecture for CRSN

The theory considers the clustering philosophy to decrease the overhead through an individual devoted control channel for each cluster chosen from the existing channel set. The CHs in each cluster become responsible both for inter-cluster communication and intra-cluster channel access control. The Gateway nodes (GWs) that revolve around the border of two neighbouring clusters enable the inter-cluster communication and allow serving both cluster beacons.

Problem Formulation:

The focus relates to reducing the congestion in the network with a view of maximizing the throughput for data transmission. It echoes to form a cluster-based HEED methodology for routing the data through a dynamic window adaptation with rate congestion control strategy in a CRSN. The exercise owes to estimate its performance on a NS2 portal and launch its merits in terms of indices through a study with DWASRCC -HEED methods.

Proposed Methodology:

The main aim augurs to avoid congestion and route the packets to the destination with the rate, energy, bandwidth of the packet, location and hop count being the terms under consideration while establishing the route. It necessitates distinguishing the loss of packets due to the link failure and congestion to regulate the sender side congestion window, accustomed using the STC. The transmission probability serves to frontward the packets into the network in case of congestion.

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It engages the bandwidth allocation based on the current requirement and adjudicates the selection of the best path in terms of the energy, mobility and bandwidth of the path. Besides it realizes the congestion rate through the AIAD and AIMD schemes with INC and DEC as the rate increasing and decreasing factors respectively.

The nodes send Hello messages to discover its neighbourhood in the sense when the node becomes ready; it checks the availability of the route to send the data. In the event of the path being unavailable, it searches an alternate route to send the data. Upon receiving the r_req message, the destination performs the best path selection and carries the path information using r_req as the unicast message.

When the incoming traffic exceeds the available network bandwidth it leads to congestion and drops the packets arriving in excess of the node's buffer capacity. The proposed method calculates the required bandwidth and accordingly enables the receiver to advertise the window size.

If the network remains fully utilized for the entire transmission, then the receiver congestion window size can be given using Equation.1

$$Receiver\ congestion\ window = RTT * BW \quad (1)$$

Where RTT relates to the time interval between the last ACK sent and the arrival of the data packet and the Bandwidth

The maximum receiver's advertisement window can be obtained from Equation.2

$$RAWD = \min\left(R_{b,} RCWD\right) \quad (2)$$

Where RAWD indicates the maximum receiver's advertised window, R_{bi} is the available buffer at the receiver, RCWD the Receiver's Congestion Window.

The transmission probability can be expressed as in Equation.3

$$Transmission\ probability = \alpha_1\left(\frac{BW}{Max\ BW}\right) + \alpha_2\left(\frac{RBL}{MBL}\right) + \alpha_3 + exp\left(\frac{Current\ window}{Max\ WND}\right) + \alpha_4 exp\left(-(\frac{RAWD}{Max\ ADWND})\right) \quad (3)$$

Where RBL denotes the Receiver buffer length of the path, MBL is the maximum buffer length, Max WND is the maximum window size and Max ADWND is the receiver advertised window.

On calculating the transmission probability, the approach allows to dynamically adapt the size of the sender congestion window using the STC, computed from the congestion window size over time period (t) and enables the bandwidth allocator to provide the available bandwidth for the current flow of data. The sink station fundamentally works the bottleneck circumvention system centrally and sends the instructions to the accumulating sensor nodes through the mutual control channel at apiece congestion announcement period T.

The terminologies in expressions 4 and 5 rule the rate based broad AIAD and AIMD arrangements to recognize the development of sending rate development

$$r_{i+1} = \begin{cases} \max(1, \left[\frac{r_i}{DEC}\right] \ with\ probability\ \Omega_{r_i} \\ max(r_i + INC\ , R_{max})with\ probability\ 1 - \Omega_{r_i} \end{cases} \quad (4)$$

$$r_{i+1} = \begin{cases} \max(1, r_i - DEC\ with\ probability\ \Omega_{r_i} \\ \max(r_i + INC\ , R_{max})with\ probability\ 1 - \Omega_{r_i} \end{cases} \quad (5)$$

Where r_i refers to the present sending rate of a accumulating sensor node and Ω_{r_i} the bottleneck probability in the well-known path among the source nodes.

The sending rate of source node relates to r_i and r_{i+1} the new attuned sending rate of the source node. The rate-based generic AIAD and AIMD arrangements surge the sending rate additively by INC factor in the absence of any congested node in the path from the source node to the sink in the congestion announcement period (T).

The *VCRH projected* as the *VCR alienated* by the number of hops in a given route serves to assess the degree of the link disagreements and if the likelihood of the channel disagreements turns out to be greater, then the MAC contention space needs to be larger and the back offtime requires a wider range to let a higher contention prospect result in a larger distinction of the contention suspension.

It eradicates the effect of the path length and attain the contention RTT to estimate the modification and then divide it by the number of hops, from where the eccentricities for each hop becomes known. The second method imposes seeing a round-trip path in its place of a forward path used in the straight method because the ACKs in the backward route exhibition to be as in significant factor for noticing link contention. The third involves to set an suitable value for the compulsory number of samples *n*, to estimate the *VCR*. However, with a large *n* it increases the memory size and the scheming cost of nodes and gradually responds to a change due to a long-term average effect.

With *n* being very small, it becomes very complex to a small change and may cause a large value of *VCRH* on different RTTs. The recursive Equations. 6 through 9 forge to update the *VCR* once the source receives a new ACK

$$E_K = \frac{E_{K-1} X (K-1) + CR_{new}}{K} \qquad for\ K < n \qquad (6)$$

$$v_k = \frac{(v_{k-1} + E_{K-1}^2) * (K-1) + CR_{new}^2 - E_K^2}{k} \qquad for\ k < n \qquad (7)$$

$$E_K = E_{K-1} + \frac{CR_{new} + CR_{old}}{N} \qquad for\ k \geq n \qquad (8)$$

$$v_k = \frac{(v_{k-1} + E_{K-1}^2) * n + CR_{new}^2 - CR_{old}^2 - E_K^2}{N} \qquad for\ k \geq n \qquad (9)$$

where *k* denotes the sampling order of the newly received ACKs, *n is* the maximum number of samples, and E_k and V_k is the expectancy and the modification of *CR* (contention RTT) from the latest *k*(when *k* < *n*) or *n* (when *k* >= *n*) ACKs.

If $k < n$, it gives the V_k because the number of sample entries k falls to be different from n. If $k >= n$, V_k it employs a new *CR* sampling value limited in a new ACK to push out an old entry n times ago, and update the *V CR* bestowing to the new *CR* value itself from where the gain *VCRH* can be got by dividing *Vk* with the number of hops.

The process owes to set a beginning parameter *VCRH_th* and if it exceeds the threshold, it discards the degree of contention in the network. When a TCP source receives a new ACK, it updates the value of the *VCRH* beforehand to check whether this value remains larger than or equal to the *VCRH_th* value. If the contention window CWND in Equation.10 becomes larger, then it decreases it by one MSS instead of an increase in the congestion window.

$$CWND_{max} = \frac{Packet\ length * RTT}{2(n-1) * max(d_i)} \quad (10)$$

Where d_i refers to the delay at node i.

The method successfully confines the congestion window from overrunning and if the RTO expires, which infers that the network exists in a bad congestion or disagreement status. It implements to check whether the *VCRH* remains larger than or equal to the *VCRH_th* before the origination of the congestion, in which case it resets the *cwnd* to 2 *MSS and empowers a process of slow-start step.

The sampling of the *VCRH* dictates to be reset after an RTO and thus the successive slow start of *cwnd* may not be exaggerated by the low value of *VCRH* gained before the RTO expires. It exhibits a large dissimilarity of the contention RTT as an evidence of the dispute status in difference and offers to be exact because it appraises the contention from a series of contention RTT values.

It removes the outmoded values long before but in the straight TCP contention control; the unfashionable contention info affects the control of V*CRH*. Besides the congestion window version mechanism seems to be meeker and upon reaction of a new ACK, the *VCRH* result specifies how the value of *cwnd* can be familiar and even if the approximation on contention may be diverse from reality, the resulting *cwnd*can be just somewhat modified.

The Fig. 2 shows the flowchart for the proposed methodology.

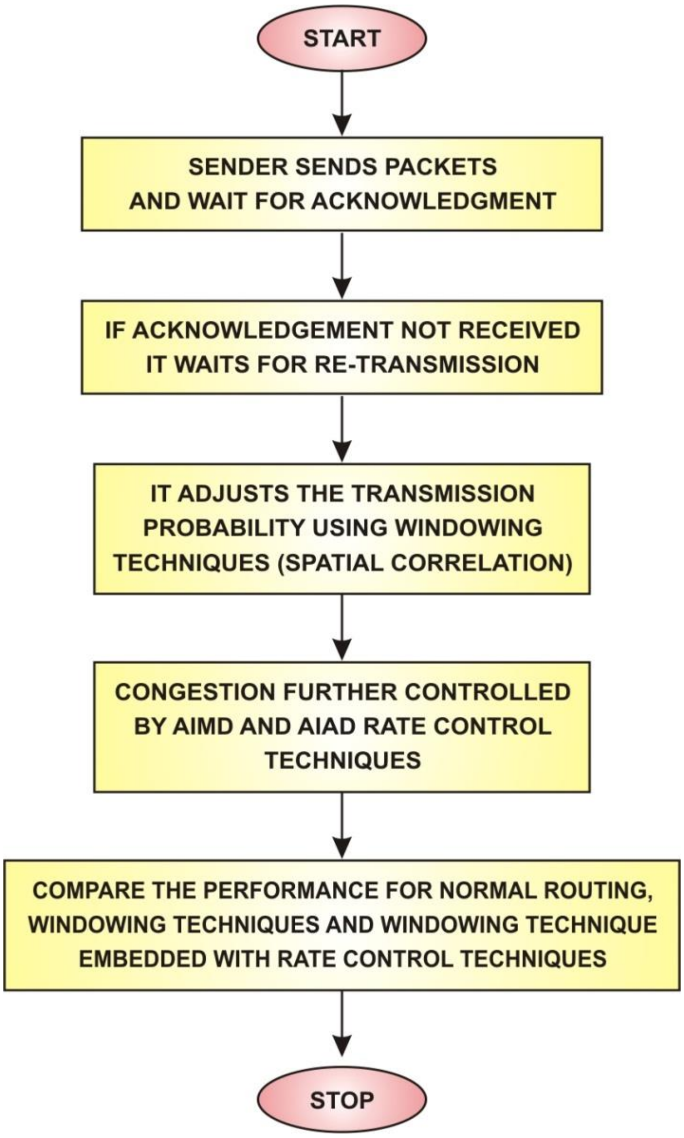


Fig.2 Flowchart for Proposed Methodology

Simulation Results:

The proposed model simulated with the nodes distributed over an area of 1000 x 1000 m^2 using NS2 platform, allows the packet size to vary from 1000 to 5000.It follows the clustered HEED routing pattern and obtains the results with the simulation parameters shown in the Table 1.

The performance fosters to establish the merits of the dynamic window adaptation technique along with the rate control technique in terms of the indices that include the PDR, throughput, delay, energy and normalized overhead.

Table 1. Simulation Parameters

Simulation parameters	Value
Sensor nodes (Numbers)	250
Communication range	250 m
Size of the Buffer	50 packets
Size of the Packet	1000 to 5000
Power (Transmission)	0.8 W
Power (Reception)	0.6 W
Simulation Time	200 s

The network PDR expressed as a line chart in the Fig.3 follows to gradually decline for the larger sized packets on account of the increased losses. However, the proposed combined approach yields the highest PDR to highlight its credibility.

The dynamic window adaptation along with rate control technique carries the highest number of packets, incurs the lowest values for losses and provide the largest throughput in comparison with the others for increasing sizes of data rates as observed from the Figs. 4 to 7 respectively.

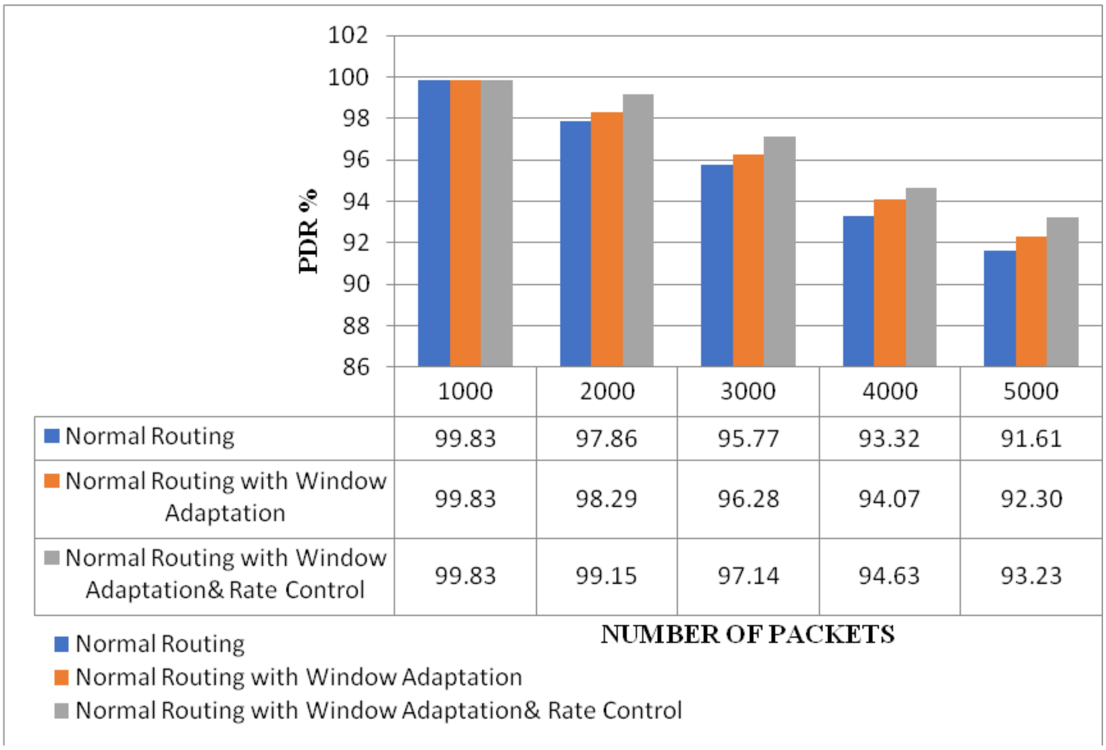


Fig. 3 PDR Vs Number of Packets

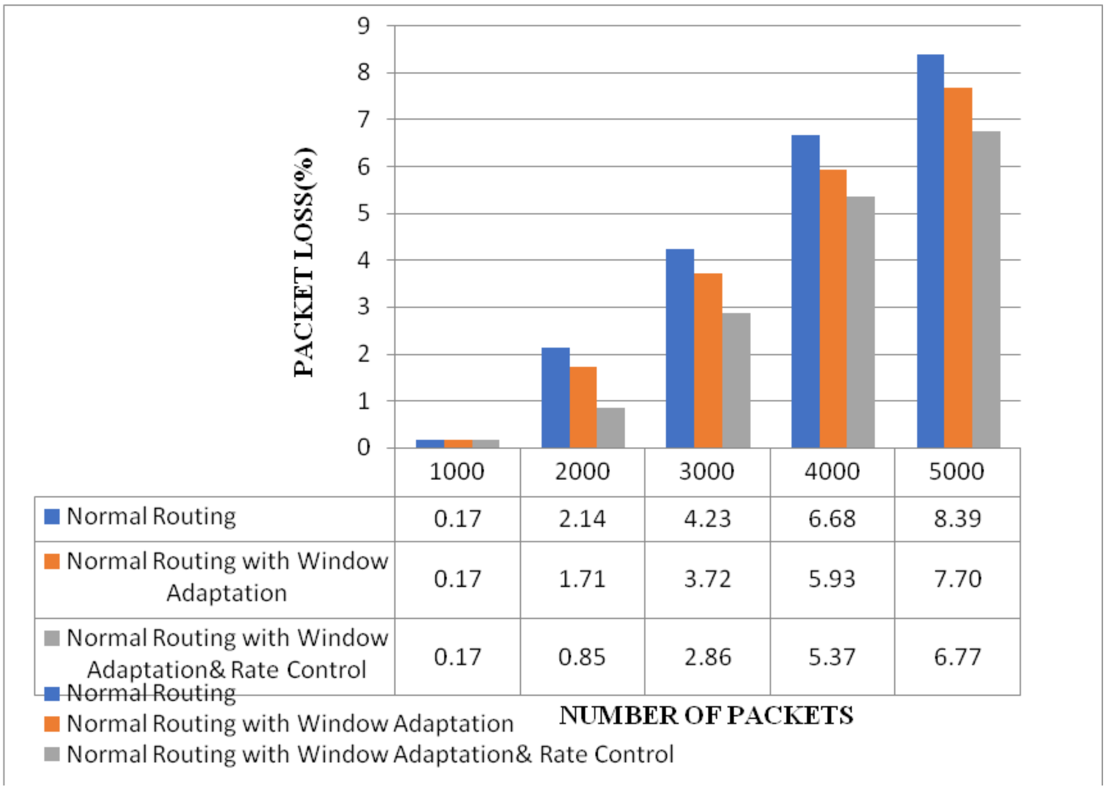
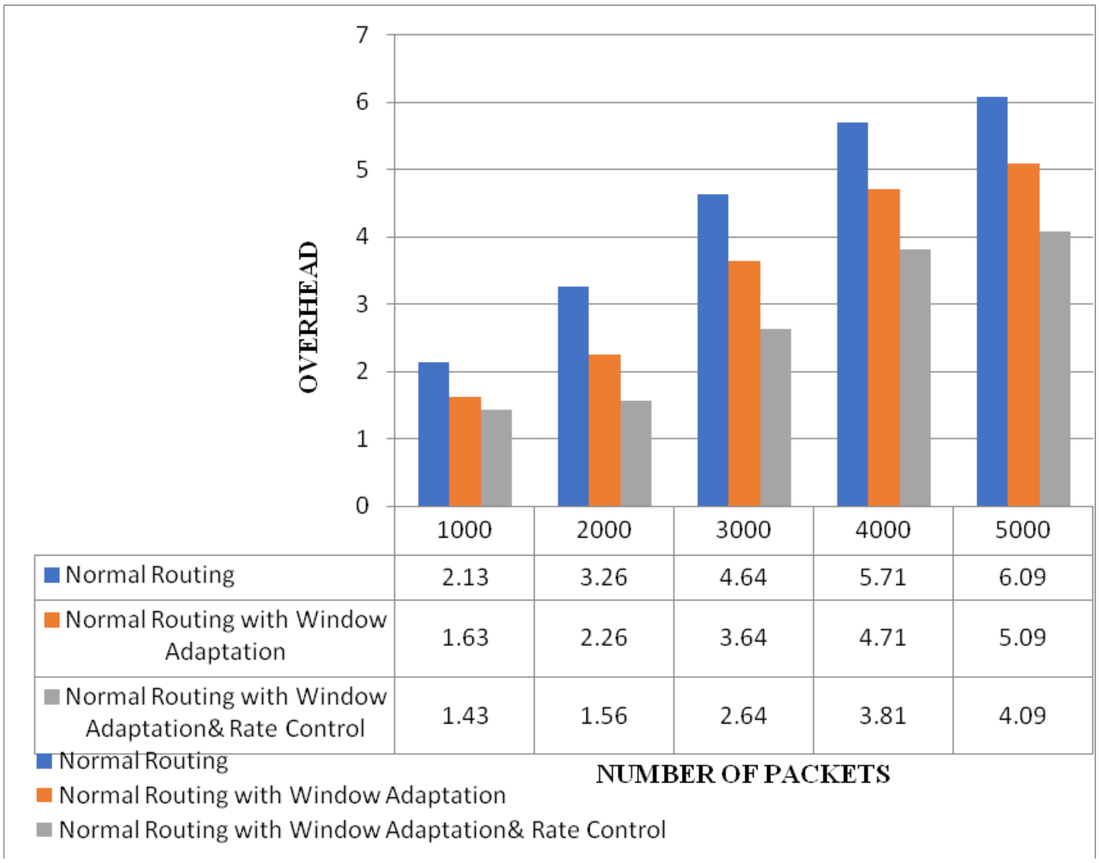


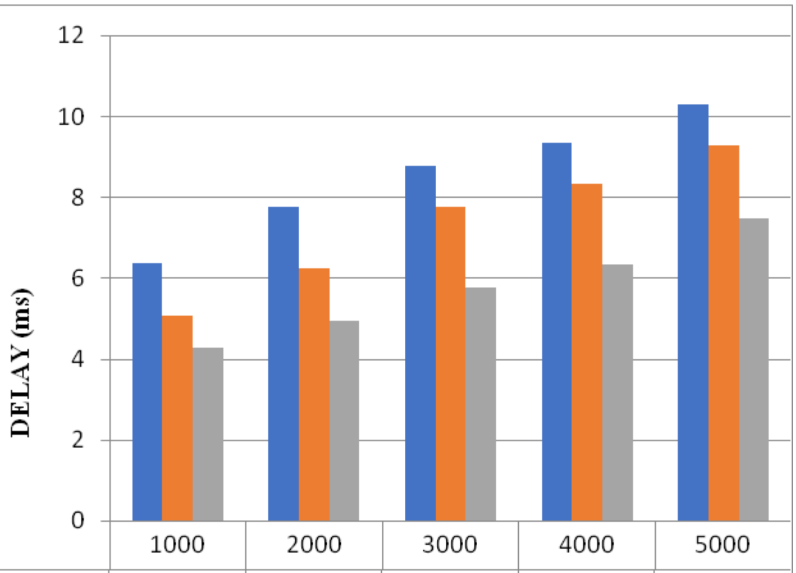
Fig. 4 Packet loss Vs Number of Packets



	1000	2000	3000	4000	5000
Normal Routing	2.13	3.26	4.64	5.71	6.09
Normal Routing with Window Adaptation	1.63	2.26	3.64	4.71	5.09
Normal Routing with Window Adaptation& Rate Control	1.43	1.56	2.64	3.81	4.09

Fig. 5 Overhead Vs Number of Packets

The Figs. 5 and 6 relate to the overhead and the delay respectively to bring about a variation as a function of the variation in the packet sizes. The delay and overhead associated with the transmission of packets accrues to be the minimum for window adaptation techniques combined with rate control over the two other schemes and favours a significant enhancement in the network service.



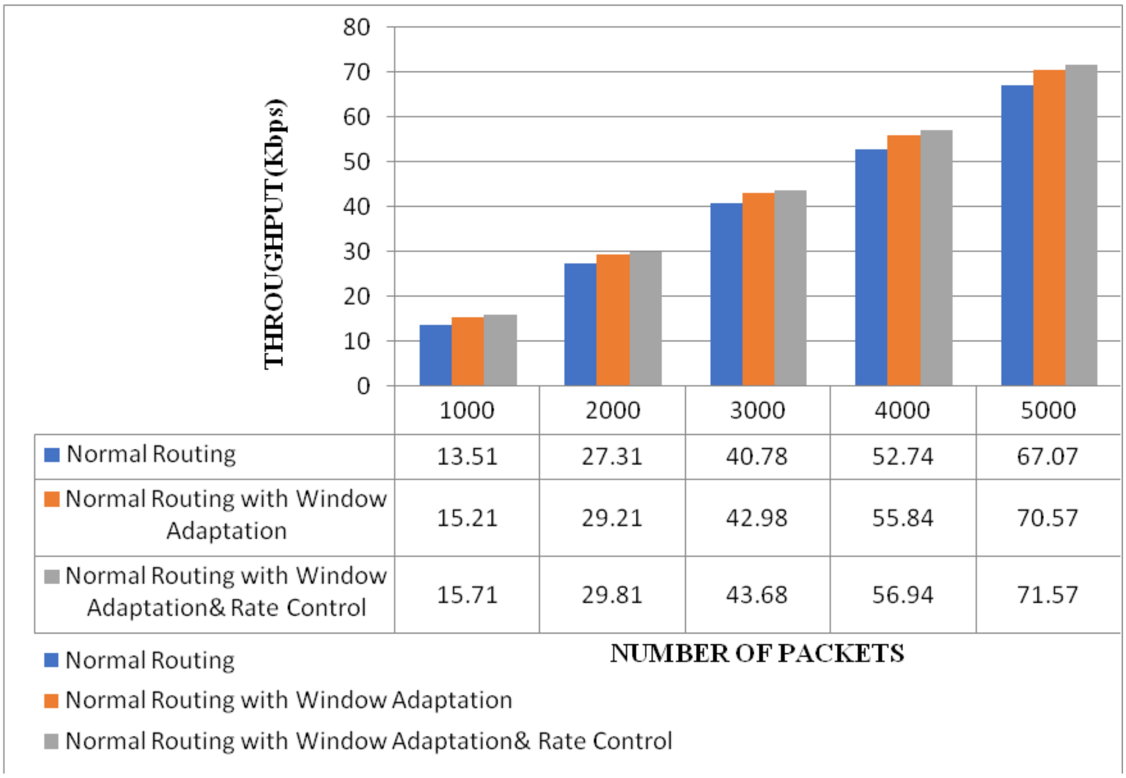
	1000	2000	3000	4000	5000
Normal Routing	6.38	7.77	8.77	9.33	10.28
Normal Routing with Window Adaptation	5.07	6.25	7.77	8.33	9.28
Normal Routing with Window Adaptation& Rate Control	4.27	4.94	5.76	6.33	7.48

NUMBER OF PACKETS

Normal Routing
Normal Routing with Window Adaptation
Normal Routing with Window Adaptation& Rate Control

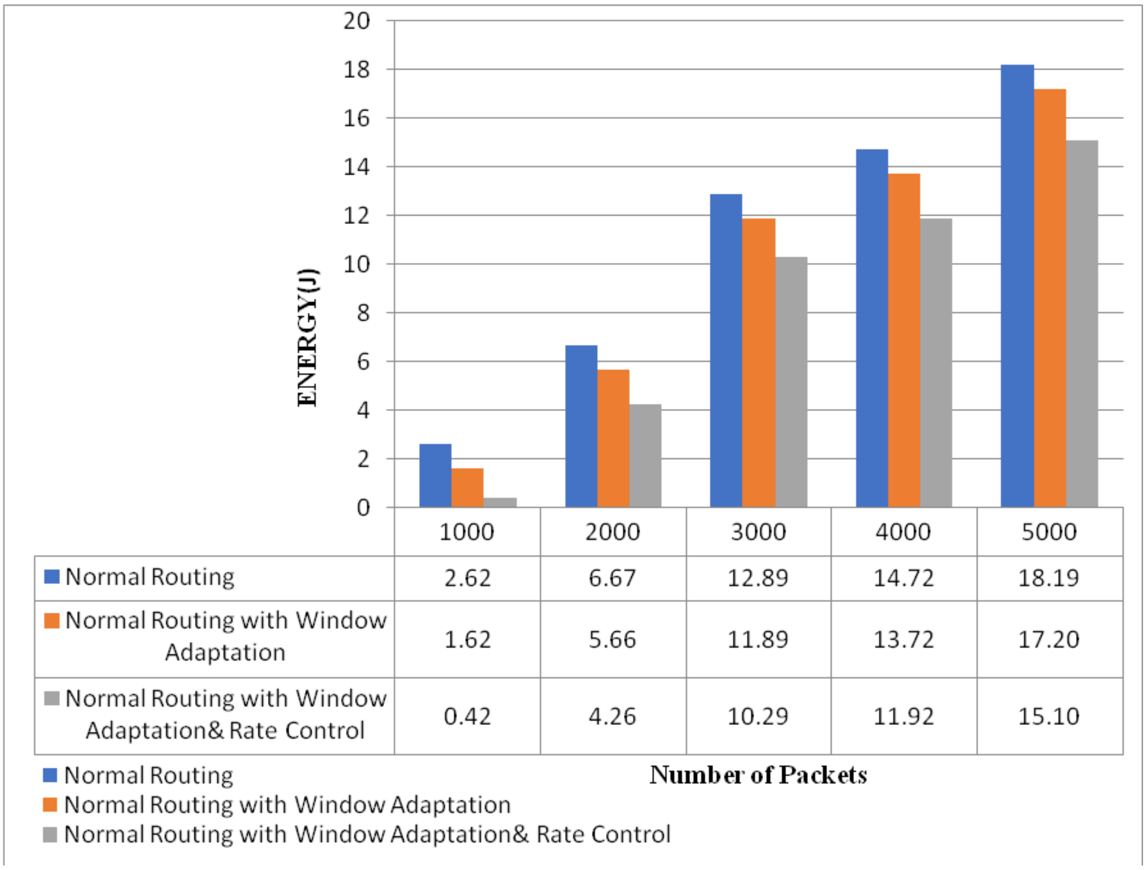
Fig. 6 Delay Vs Number of Packets

The bar diagrams in the Figs. 7 and 8 explain the benefits of combining the window adaptation techniques together with the rate control techniques to offer a higher throughput and enjoy an energy efficient characteristic over the other methods and leave way to increase the network lifetime.



	1000	2000	3000	4000	5000
Normal Routing	13.51	27.31	40.78	52.74	67.07
Normal Routing with Window Adaptation	15.21	29.21	42.98	55.84	70.57
Normal Routing with Window Adaptation& Rate Control	15.71	29.81	43.68	56.94	71.57

Fig.7 Throughput Vs Number of Packets



	1000	2000	3000	4000	5000
Normal Routing	2.62	6.67	12.89	14.72	18.19
Normal Routing with Window Adaptation	1.62	5.66	11.89	13.72	17.20
Normal Routing with Window Adaptation& Rate Control	0.42	4.26	10.29	11.92	15.10

Fig.8 Energy Vs Number of Packets

CONCLUSION:

A clustered HEED data transfer strategy has been formulated for the cross layered CRSN through the DWASRCC technique to detect and avoid traffic congestion. The performance has been measured using the indices that include the throughput, PDR, packet loss, delay, overhead and energy both before and after the dynamic adaptation and rate control to claim the benefits of the sensing process. The results have been forayed to elucidate the merits of the cluster based DWASRCC-HEED approach for routing the information in a congestion free environment and accrue the benefits of an improved network service.

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