Energy Aware Cluster Based Multiplexed Routing Strategy for Wireless Sensor Network

Santhana Krishnan. B and Ramaswamy. M

Abstract— The paper invites the philosophy of time division multiplexing to the theory of data transfer in a Wireless Sensor Network (WSN). It endeavors to realize a Single Input and Single Output (SISO) framework on the boundaries of minimum use of energy with a view to increase the network life time. The mechanism assuages the formation of a clustered environment to articulate the realms of an Ad-hoc On demand Distance Vector (AODV) routing mechanism in an effort to eschew an energy efficient path for the delivery of information. The role of a Cluster Head (CH) aids in the process of creating a single path at a given time and engraves a perspective to address the demands of the increasing traffic. It augurs to reduce the consumption of energy required to carry the message from the source to the destination in the periphery of the chosen architecture. The simulation results in the Network Simulator (NS2) platform measured in terms of the performance indices exhibit the merits of the Cluster Based Ad-hoc On demand Distance Vector (CAODV) scheme over similar approaches and erudite a new road map in the context of data communication for WSN.

Index Terms— CAODV, Energy Efficiency, Multiplexing, Network Lifetime, SISO, Wireless Sensor Network.

I. Introduction

Wireless sensor networks (WSNs) emerge as a new paradigm in the creation of a true ubiquitous and smart environment to capitalize on the interface infrastructure with external networks and devices. It fosters sensing and actuation at a fine grained level, both spatially and temporally in the process of monitoring, collecting the data, assessing and evaluating the information to pronounce its transfer within the network. The resulting characteristics turn out to be attractive for both commercial and military communication networks [1, 2] to support control and automation of physical entities [3].

The use of wireless technology echoes an increasing role in sensor networks in view of the fact that the present environment perpetuates to exploit the wireless capability in laying down error-free communication channels and assuaging perfect synchronization between the service nodes [4]. The design of distributed sensor networks espouses to account for the effects of channel-induced interference along with timing and frequency offsets in ensuring a smooth delivery of packets. It entails to increase the reliability and promote a fault tolerant nature by combining the information from distributed sensors located in the network.

The exigent energy levels exhibit inconveniences in the form of limited computational power and coverage for the network. The challenges evince in coping with resource constraints placed on individual sensor devices and calls for measures to minimize power consumption [5]. The advent of new technologies allows wireless monitoring systems to shrink in size, cost, energy requirements and maximize their operational lifetime.

The Single Input and Single Output (SISO) form a simple communication system with a single transmitting antenna at the source and a single receiving antenna at the destination [6, 7]. The system though diverse in nature, allows its throughput to depend on the channel bandwidth and signal to noise ratio. It however experiences several issues like fading, losses and attenuation to result in the reduction of data speed. There arises a need to explore on avenues for effectively routing the data through the indeterminate mobile nodes within the network and augur an energy efficient perspective to the process.

A Time Division Multiple Access (TDMA) based Medium Access Control (MAC) has been proposed to conserve energy and increase data transmission efficiency of sensors in a cluster based WSN. While the nodes with no data has been designed to go to the sleep mode, that large amount of data seek additional time slot from the Cluster Head (CH) for transmitting the data [8]. A multi objective TDMA scheduling problem has been outlined for many to one sensor network to save energy on account of the state transition between active and sleep mode. A hybridized optimization frame work with both Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) has been created to enhance the certain ability. The simulation results have been presented for different network sizes to display its superior performance over three other algorithms in terms of the total energy consumed per data collection [9]. A TDMA based scheduling scheme has been suggested to balance the energy saving and end to end delay in a WSN. The methodology has been framed by appropriate scheduling of wake up interval and allows the delay of data packet by one sleep interval for an end to end transmission from the sensors to the gate way [10]. A time synchronization algorithm has been operated within the TDMA schedule to reduce the end to end latency and enhance the stealing opportunity. The slot across the TDMA cycles has been scheduled for downstream control and upstream data messages. The simulation studies have been interleaved to provide higher peak throughput and improve the average packet latency over the other existing TDMA

Manuscript received November 24, 2014

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protocols [11].

A time division multiplexed MAC protocol has been introduced to suit centralized cluster routing in WSN. The results have been shown to reduce the energy consumption and prolonging the network life cycle [12]. A TDMA based MAC protocol has been proposed to offer an efficient energy support for cluster mobility in WSN. A hybrid contention free and contention based communication approach has been laid to relieve a protocol from rescheduling demand due to frequent node movement. A concurrent mechanism has also been incorporated to avoid ideal listening lead to a considerable energy saving for mobile node [13]. An energy efficient sleep scheduling mechanism has been designed for low data rate WSN. A contiguous link scheduling scheme has been framed to assigned sensors with consecutive time slot and reduce the frequency of state transitions [14]. An energy aware Advanced Medium Access Control (A-MAC) protocol has been formulated to reduce the ideal energy consumption and implement after sleep theory for the node in a WSN. The modeling results have been obtained to prolong the network lifetime owing to the efficient time slot management [15].

Despite the fact that innumerable time division multiplexed approaches do exist for a variety of WSN platforms its influence on a SISO framework leaves a lot to be edified and calls for an energy efficient mechanism to transfer the data in order that it enhances the performance of the network in terms of indices.

II. PROBLEM DESCRIPTION

The main objective utters to attach a time division multiplexed format for the transfer of data through mobile intermediate nodes in a WSN. The methodology owes to encrypt an energy efficient path and facilitate an enhancement in the network life time. The procedure endeavors incorporating the principles of a cluster to an Ad-hoc On demand Distance Vector (AODV) strategy for routing the packets across the prioritized source and destination outfits [16]. It centers on the function of a CH in its efforts to decide on the choice of the preferred path. The focus spreads to use the Network Simulator (NS2) platform for evaluating the performance of the methodology and realize its flexibility in the transmission of information.

III. PROPOSED APPROACH

The reliable operation of a wireless sensor network relates closely to the ability of the sensor radios to successfully communicate with each other. The theory of routing evinces challenges due to the inherent characteristics that distinguish these networks from other wireless networks like mobile ad hoc networks or cellular networks. The ad-hoc deployment of the sensor nodes requires the system to form connections and result with a formidable nodal distribution to accede easy transfer of data.

Inadequate resources find it difficult to cope with unpredictable and frequent topological changes especially in a mobile environment and besides data collection using many sensor nodes usually results in a high probability of data redundancy. The bounded latency for data transmissions enforces consideration in light of the fact that energy conservation assumes importance over Quality of Service (QoS). It follows the predicament that the sensor nodes become constrained with energy which owes a direct relationship to network lifetime.

The capacity of SISO systems relates the bandwidth (B) and the signal to noise ratio (S/N) through the Shannon's capacity equation as in Eqn. 1

$$C = B\log(1 + S/N) \text{ -------- } (1)$$

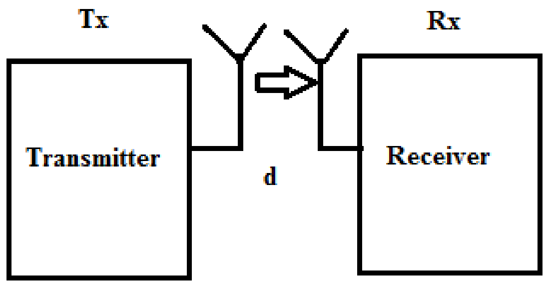

Figure1. SISO Wireless System

The presence of a single transmitter and receiver deduces the total energy consumption to be the sum of total power consumed by transmitter P_t and receiver P_r which combine in Eqn. 2 to give the energy consumed by a unit bit.

$$En_{siso} = (P_t + P_r)/T_{dr} \text{ -------- } (2)$$

Where, T_{dr} refers to the transmission data rate.

The power required for transmitting the data in Rayleigh fading channel can be calculated by simplified path loss model (log-Distance path loss). On the assumption that the transmitter antenna gain G_t and receiver antenna gain G_r to be equal to 1, the P_t calculates from Eqn. 3

$$P_t = P_c + \frac{(4\pi)^2\, P_{reci}\, d^{\alpha}}{d_0^{\alpha-2}\, \lambda^2} \text{ -------- } (3)$$

Where the symbols P_c, P_{reci} , $\lambda = c / f_c$, respectively govern the power consumed by transmitter circuitry, the power of received signal, c the speed of light, f_c the carrier frequency, α the path loss exponent, d the actual distance between transmitter and receiver and d_0 the reference distance for far-field region.

The minimum received power required P_{reci} in Eqn.4 accomplish the desired Bit Error Rate (BER)

$$P_{reci} = P_{rxs} \times R_{eber} \text{ -------- } (4)$$

Where P_{rxs} is the receiver sensitivity and P_{rxs} is the E_b/N_o (in Watt).

The R_{eber} may be calculated as in Eqn. 5

$$R_{eber} = \frac{((1-2\,P_r)^2)\,/(1-(1-2P_r)^2)}{\left(er_{fn}^{-1}(2\,P_r)\right)^2} \text{ -------- } (5)$$

Where er_{fn}^{-1} accounts for the inverse of the complimentary error function i.e.

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$$er_{fn}(x) = \frac{2}{\sqrt{\pi}} \int_{x}^{+\infty} e^{-t^2}\, dt \text{ ------ (6)}$$

Using equations (3), (4), (5) and (6), the total energy consumed by SISO may be written as in Eqn.7

$$En_{siso} = \left(\left(P_c + \frac{(4\pi)^2\ P_{rxs} \times R_{eber}\, d^{\alpha}}{d_0^{\alpha-2}\, \lambda^2} + P_r\right)\right) / T_{dr} \text{ ----- (7)}$$

The total power consumption P_T in Eqn. 8 totals the sum of power consumption of the power amplifiers P_A and the power consumption of the other circuit blocks P_C.

$$P_T = P_A + P_C \text{ ----- (8)}$$

The amplifier power can be determined from the Eqn. 9

$$P_A = P_O + \alpha P_O \text{ ------ (9)}$$

If the channel only experiences a kth power path loss with Additive White Gaussian Noise (AWGN), the P_O can be computed on the lines of the link budget model as in Eqn. 10

$$P_O = E_b R_b \times \frac{16\, \pi^2\, d^k}{G_t G_r \lambda^2} L_M N_F \text{ -------- (10)}$$

Where E_b echoes the average energy per bit required for a given BER specification, R_b is the transmission bit rate, d is the transmission distance, λ is the carrier wavelength, L_M is the link margin compensating the hardware process variations and other background noise, N_F is the receiver noise figure defined as $N_F = N_r/N_0$ where N_r is the Power Spectral Density (PSD) of the total effective noise at the receiver input and N_0 is the single-sided thermal noise PSD at the room temperature.

The design of routing methods carry measures to ensure energy efficiency and provide an increasing lifetime for the sensor nodes in a WSN. The theory of clustering forays a prodigy to serve as an effective communication mode and involves two phases in the process [16]. It consists in selecting the nodes with the highest energy as cluster heads from the set of sensor nodes and allows the remaining nodes to regroup around them. The cluster members thereafter transfer the data through the CH which in turn decides the path for it to reach the destination. The nodes in cluster attempt to balance the network energy consumption and follow the minimum energy path to prolong the lifetime.

The role of a clustered based data forwarding mechanism formulates to conceive an energy efficient methodology where the sensor nodes organize themselves into clusters, with each member node belongs to only one cluster. The data collected from sensors travel to the CH and thereafter reach the destination. The high density of sensor networks may lead to multiple adjacent sensors generating redundant sensed data and augur the need for eliminating data redundancy to reduce the communication load.

IV. SIMULATION RESULTS

The methodology envisages investigating the performance of the CAODV routing pattern of a WSN configured with two hundred intermediate mobile nodes distributed in a space of 1000 m X 1000 m as depicted in Fig.2. It revolves around a process of transferring data between three source and destination nodes. The exercise endeavors determining a high energy node as the CH and augurs to group the intermediate nodes into several groups of clusters.

The CH facilitates the choice of the minimum energy path and the scheme thereafter allows the network to deduce into SISO architecture in order that it enjoys the lowest expenditure of energy for the data transfer. The mechanism involves the role of NS2 platform to obtain the nature of variations of the performance indices for a data flow of 3000 Kbps over a specific time frame of two hundred seconds. The study owes to evaluate the relative merits of the transfer of information from the source to the user entities through the use of three similar routing schemes that include Original Ad-hoc On demand Distance Vector (OAODV), Improved Ad-hoc On demand Distance Vector (IAODV) and the Adaptive Cluster Based Routing Protocol (ACBRP) .

The procedure evaluates using NS2 graphs the performance in terms of indices that include Packets Received, Packet Loss, Throughput, Energy Expended and Routing Delay. The variation of energy usage to accomplish the transfer of data from the three sources to the destinations seen in Fig 3 serves to foresee the minimum energy path and the theory of translation of the network into a SISO architecture displayed in Fig. 4 facilitates the process of routing. The Figs. 5 through 9 explain the variation of the metrics for the transfer of the chosen packet size in the predetermined path.

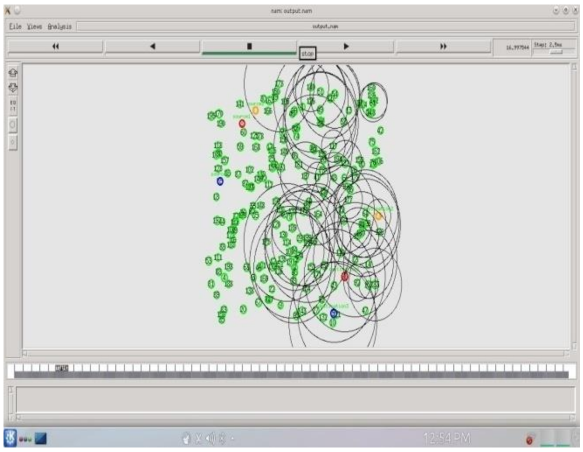

Figure2. Network Model

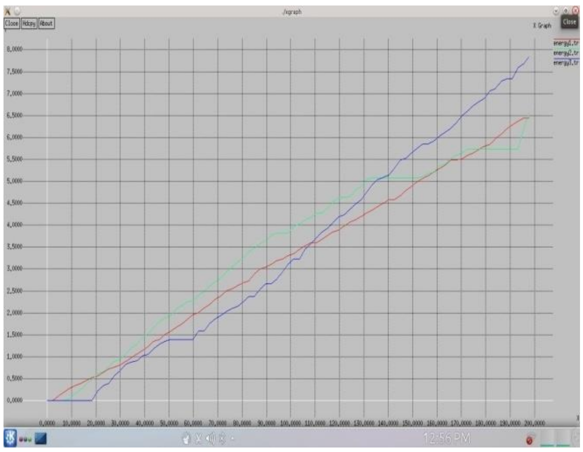

Figure3. Energy Comparison

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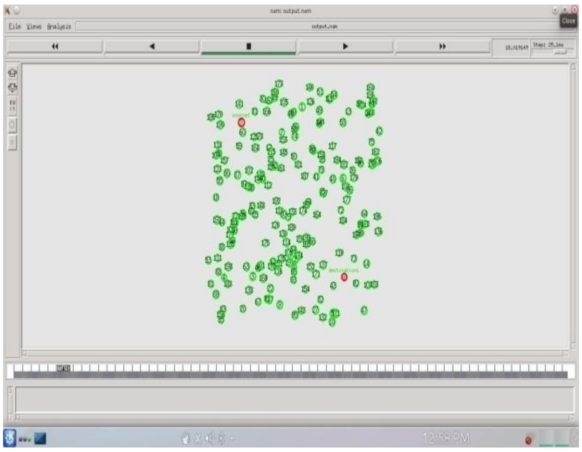

Figure4. Reduced SISO Network

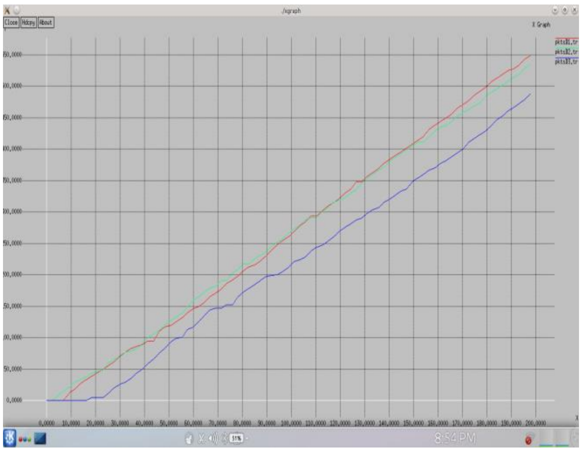

Figure5. Packets Received vs Time

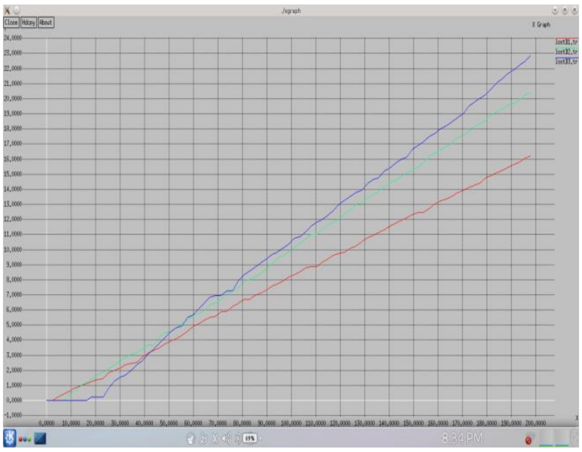

Figure6. Packet Loss vs Time

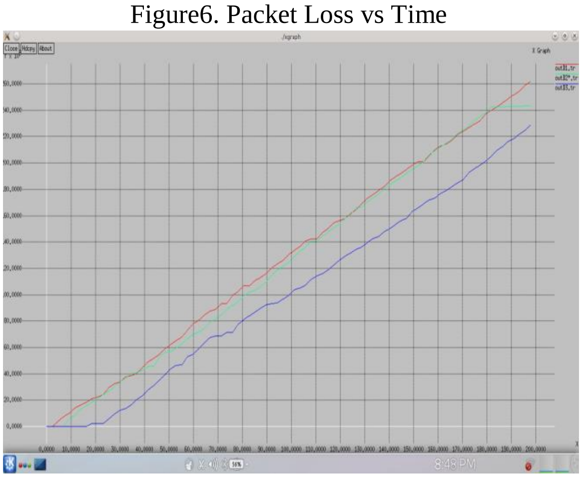

Figure7. Throughput vs Time

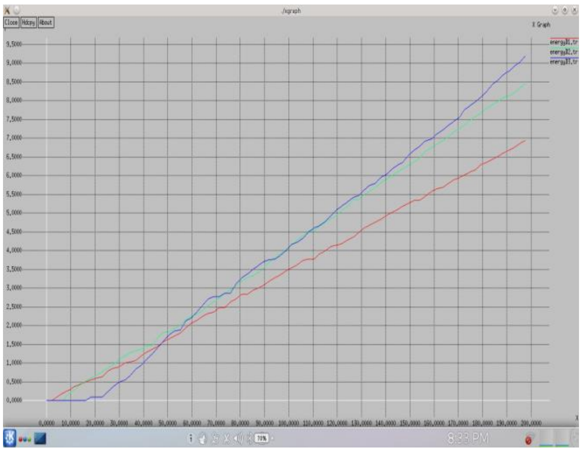

Figure8. Energy Consumed vs Time

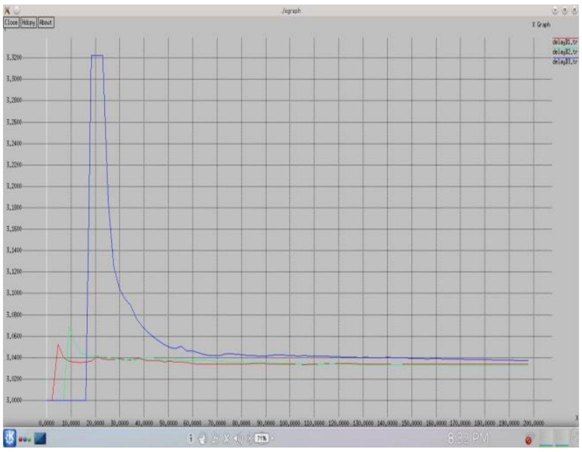

Figure9. Routing Delay vs Time

The exercise stretches to erudite the preference for CAODV over the other routing strategies through a systematic increase in the packet size ranging from 1000 to 5000 for the same interval of time in the energy efficient path. The indices measured using bar diagrams in Figs.10 to 14 acquires the best performance for CAODV over its counter parts. The Fig.15 relates to the product of Energy x Delay drawn with a purpose of enumerating the higher speed of transfer for CAODV and portraying its capability to suit the needs of the present traffic environment.

The progressively slower decline of the network Packet Delivery Ratio (PDR) seen in Fig.16 brings out the forthwith merits of CAODV in light of the congested traffic scenario and augurs its role as a viable routing scheme.

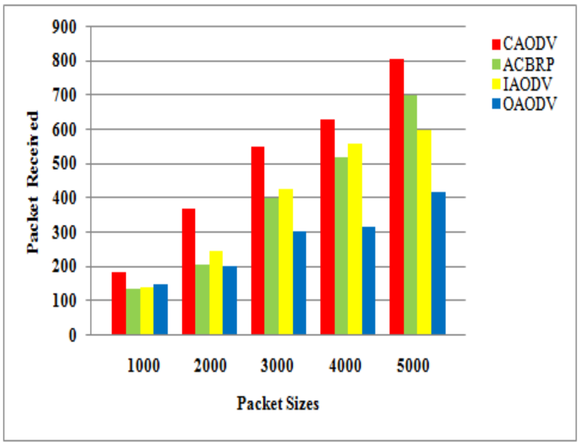

Figure10. Packets Received vs Packet Sizes

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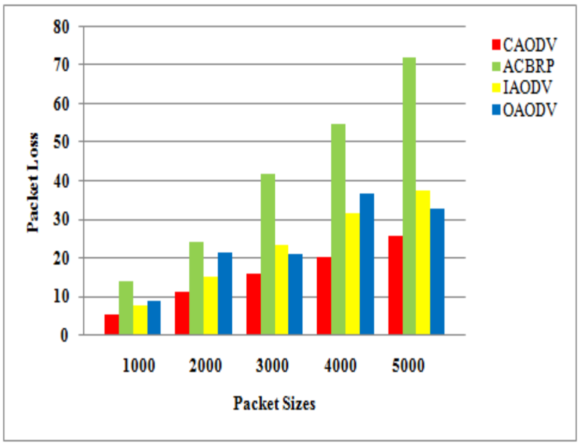

Figure11. Packet Loss vs. Packet Sizes

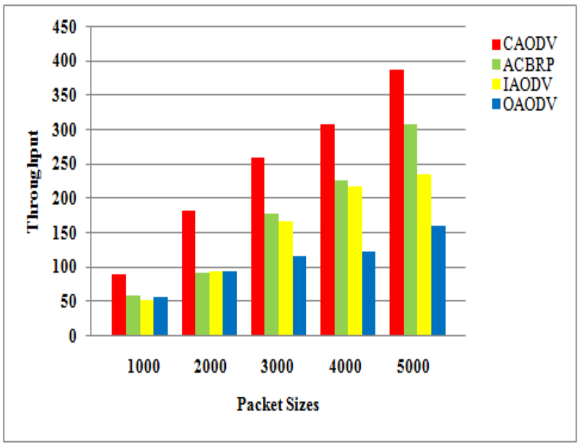

Figure12. Throughput vs Packet Sizes

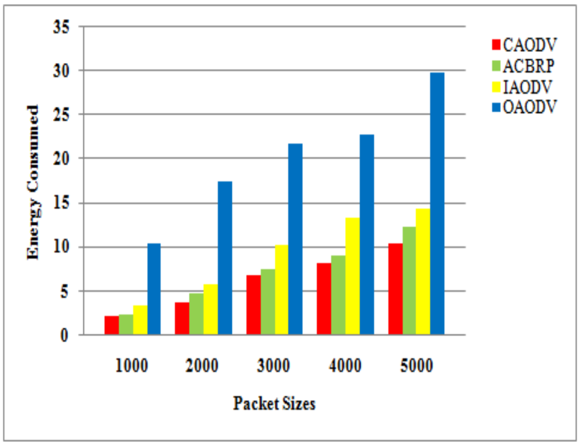

Figure13. Energy Consumed vs Packet Sizes

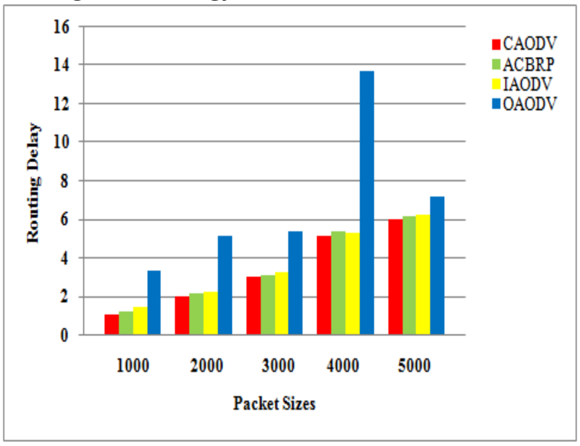

Figure14. Routing Delay vs. Packet Sizes

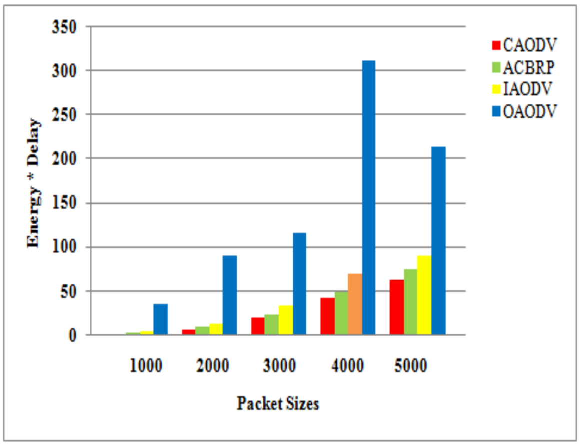

Figure15. Energy * Delay vs. Packet Sizes

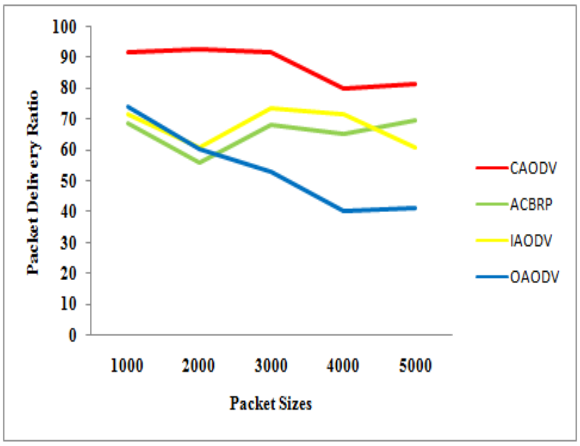

Figure16. Packet Delivery Ratio vs Packet Sizes

V. CONCLUSION

A SISO configuration has been articulated to evince data transfer in a three source – three destination node network through the principles of time division multiplexing. The philosophy of radio energy model has been incorporated to carry the information within the boundary of a WSN. The transfer of packets has been relayed using the formulation of CAODV routing to capitalize on the benefits of energy efficiency. The NS2 simulation study has been cornered to acclaim the best performance for this cluster based approach in an effort to increase the network life time. The true nature of the mechanism to adapt to higher sized packets has been vitiated with admirable levels of indices. The higher network PDR, the CAODV accrues over the other schemes in the same platform has been espoused to allow it to be suitable in the realms of a smooth communicative mobile medium.

ACKNOWLEDGMENT

The authors thank the authorities of Annamalai University for providing the necessary facilities in order to accomplish this piece of work.

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