Cluster Based Data Transfer Strategy for Layered Wireless Sensor Network

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Abstract

The paper develops a relatively different cluster based data transfer pattern directed to enhance the lifetime of a layered Wireless Sensor Network (WSN). The interactive information flow between layers appears to captivate the resurgence of new definitions in the process of routing and forge attractive corner stone's in communication networks. It involves the use of an Ad-hoc On demand Distance Vector (AODV) format and edges on the borders of minimal energy consumption, adaptive communication decisions and local congestion avoidance to fulfill the needs of a modern communication platform. The proposed Cluster based Ad-hoc On demand Distance Vector (CAODV) approach offers an energy efficient formulation to effectively utilize sensor and actuator interface and proliferate a new dimension in the domains of a WSN. The role of a Cluster Head (CH) adds weight to the prophecy of conserving energy for the power source and translates the diminishing need of energy to force the data stream to the destination. The Network Simulator (NS2) simulation results show that the design significantly improves the transfer efficiency and outperforms that of the layered routing schemes.

Keywords: *Wireless Sensor Network, Layered Approach, Network Lifetime, Energy Efficiency, Routing.*

1. Introduction

A collection of nodes organized into a cooperative network and accommodate various sensors and actuators along with a power source constitute a Wireless Sensor Network (WSN). The nodes communicate wirelessly and often self-organize themselves after being deployed in an ad-hoc fashion. The basic operation in such a network involves the systematic gathering and transmission of sensed data to a base station for further processing. The large number of untethered sensor nodes offer different services that include data transferring, tracking small animals and targets, environmental monitoring and enforcing security perimeters [1].

The WSN partitions itself with nodes that inherit the same hop count to the sink into different layers [2] to form a layered architecture. The geographical distribution of the nodes together with the sink location determines the number of layers and the number of nodes in each layer. The sensor nodes close to each other group themselves into a cluster [3] and the nodes in the same layer select a node in its adjacent layer closer to the sink as the forwarding node called the Cluster Head (CH). The CH in the layered architecture locates itself closer to the sink and relays the data to the sink with less energy consumption. The nodes in the cluster send their data to a local CH from where the data reaches the sink node.

A major problem for many sensor network applications revolves around the feature to determine the most efficient way of conserving the energy of the power source. Severe energy constraints of battery-powered sensor nodes necessitate energy-efficient routing strategies in order to comply with the requirements of WSN. However, the vast majority of the existing solutions hovers over classical layered protocols and endear alternative attributes to realize better and faster transfer of data [4, 5].

A hierarchical routing algorithm has been presented for large multi layer architecture WSN. The scheme has been shown to admit simple and decentralized routing, easily extendable and fault tolerance in its approach [6]. The performance has been compared using end to end delay and success data delivery ratio with other protocol. A unified cross layer protocol has been developed and operation governed by the concepts of initiative determination [7]. The theory of Ad-hoc On demand Distance Vector (AODV) has been modified to discover an efficient energy aware routing scheme in Mobile Ad-hoc Network (MANET). The scheme has been oriented not only to use the node energy effectually but also find the best route and increase the life time of the network [8]. It has been centered on received based contention and distributed duty cycle approach to realize efficient and reliable communication. A cross layer design has been proposed for low energy self organizing protocol to suit target tracking in dense WSN [9]. A target localization algorithm has been implemented and Quality of Services (QoS) knob used to control the tradeoff between the tracking error and network energy consumption. Multi level multi hop network architecture has been suggested for WSN and a unified frame work encompasses network organization along with routing protocol outlined [10]. The single layer tree based scheme has been formulated to reduce the number of control packets and turnout to be collision free and energy efficient. A cross layer architecture widely different from traditional ad-hoc network has been forrayed to be suitable for WSN [11]. The theory of Multiple Access Control (MAC) protocol has been incorporated to evolve to optimise network protocol and results seen to yield a longer network lifetime. A multilayered strategy has been laid to provide scalable and adaptive method for handling data on a WSN [12]. The methodology has been demonstrated by a real world oceanographic deployment of a system to lead to an increase in use of network computational devices. A two layer heterogeneous sensor network has been conceived to offer better scalability using the hierarchical principles [13]. The problem of CH selection for large and dense MANET has been investigated with distance and size constraint [14]. The result of two distributed selection algorithm, each with varying logarithmic approximation ratio has been displayed to yield a robust connectivity within the network. The division of clusters in the network into sectors has been contemplated and found to lower the active time of the sensors. The theory of clustering has been advocated to perform aggregation of data and formation of network [15]. The impact of localized algorithm has been investigated with the focus to minimize the energy consumption. The cross layer design based on the theory of node interactive concept has been implemented to provide geographical routing in WSNs [16]. The simulation results have been detailed to claim information fidelity and energy efficiency besides reliable and efficient data transmission.

However with the increasing traffic around the bounds of a wireless network invites attention to conceive layered topologies and explore the suitability of cluster based routing strategies to disburse the data.

2. Problem Description

The focus endeavors to create a pattern for the transfer of data between source and destination outfits in different distinct layers of a WSN. The procedure centres around the use of a Cluster based Ad-hoc On demand Distance Vector (CAODV) to elicit the flow of packets through mobile intermediate nodes spread over the layered architecture. The choice of a CH assumes significance to realize an energy efficient routing and foster the increase in network life time. It avails the use of a Network Simulator (NS2) platform to evaluate its performance in terms of indices and establish the suitability of the approach for varying sizes of information.

3. Proposed Approach

The theory of clustering owes to improve network lifetime, a primary metric for evaluating the performance of a sensor network. The CHs and member nodes lie distributed across the two layers of the network. In view of the fact that CHs often transmit data over longer distances, they tread to lose more energy compared to the member nodes and require the network to be re-clustered periodically in order to select energy-abundant nodes to serve as CHs. Besides achieving energy efficiency, clustering reduces channel contention and packet collisions, resulting in better network throughput in a higher traffic scenario.

The nodes in the network group themselves into layers and each layer selects several nodes as CHs with maximum residual energy. The non CH nodes join together to form clusters wherein the CH nodes receive the data from the cluster members and transmit the same to their upper layer. Each sensor node in the cluster checks the signal strength and layer field of the CH to estimate its distance to the CH *(d_{CH})* using Eqn. 1.

$$d_{CH} = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r}{P_r}} \text{----------} (1)$$

Where P_t is the transmitted power, P_r is power received by the sensor node, G_t is transmitter CH antenna gain, G_r is receiver CH antenna gain and λ is wavelength of the CH in the assumed free space propagation. The sensor node then assigns itself to layer k (1 < k < L) as expressed through Eqn. 2.

$$\frac{(k-1)d}{L} < d_{CH} \le \frac{kd}{L} \quad \text{----------} (2)$$

Where *d* is the cluster radius. The cluster divides itself into L concentric layers each with width d/L and the layer boundaries determined through the application of the signal strength and allows the layers to be distributed over the cluster.

The transmission power can be adjusted by suitably configuring the power amplifier and the energy dissipation in transmitting one unit of data message over a directed wireless communication link modelled as seen from Eqn. 3.

$$\left.\begin{aligned} E_t(i) &= E_{elec} + E_{amp}(d_{i,j}) \\ E_t(i) &= E_{elec} + E_{fs} * d_{i,j}^2 \end{aligned}\right\} \text{-----------} (3)$$

Where E_{elec} denotes the energy for driving the electronics, which depends on various factors including digital coding, modulation, filtering, and spreading of the signals, E_{fs} is the coefficients of transmitter for calculating the amplifier energy E_{amp}, which depends on the Euclidean distance $d_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$ between transmitter v_i located at (x_i, y_i) and receiver v_j located at (x_j , y_j) as well as the acceptance bit-error rate. The energy consumed by a sensor v_i in receiving one unit of data packet denoted as E_r (*i*) is equal to E_{elec} and avoids interferences from simultaneous transmission.

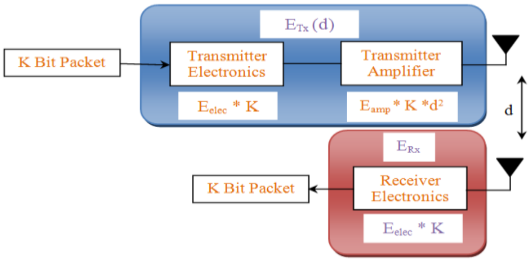

Figure1. First order Radio Energy Model

The CH gathers data messages within the cluster and forwards the same to the Base Station (BS) or sink with a constant E_P to represent the energy spent in transmitting the sensed data. The first order radio energy model seen in Fig. 1 controls the power to minimize the energy required for transmission. The energy spent for transmission of a 'K' data over a distance 'd' is represented in Eqn. 4.

$$E_{Tx}(K,d) = \begin{cases} E_{elec} * K + E_{fs} * K * d^2, \ d < d_0 \\ E_{elec} * K + E_{mp} * K * d^4, d \geq d_0 \end{cases} \text{-- (4)}$$

Where D_0 is the distance threshold and the energy consumption for receiving K data can be related as shown in Eqn. 5.

$$E_{Rx}(K) = K * E_{elec} \text{---------- (5)}$$

The power required by the transmitter can be represented using Eqn. 6.

$$P_{Tx} = P_{elec} + P_{rf} \text{ ---------- (6)}$$

Where P_{elec} and P_{rf} denotes the power consumption on the electronic circuit and RF front end, respectively. The P_{elec} is quite stable and independent of the RF output transmission power P_{out}, while P_{rf} indicates the transmission range and RF output power P_{out} *for* a given data rate and modulation scheme.

The mechanism serves to carry a packet through the layered network using the clusters and attempts to increase the throughput, lower the packet loss, reduce the delay and enhance the energy efficiency. The methodology relates to articulate a cluster based procedure and insert the role of an on-demand formulation to decide the routes for the transmission of data packets [17].

The primary theory corners to formulate an energy efficient routing platform through a process of foreseeing shorter distances for data transfer. The procedure acquits the high energy node as a CH and imbibes it as a hub to transmit the packets to the destination node. It involves a two phase mechanism to acquire the data and follow it up with subsequent choice of CHs to augment the decrease in energy level. The next stage corners to attach a search sequence to discover fresh routes to arrive at the end node through large neighbourhoods.

4. Simulation Results

The study echoes to investigate the performance of the network depicted in Fig.2 with three source and destination nodes in separate layers to transfer data in a network with two hundred intermediate mobile nodes arranged in a space of 1000 m X 1000 m. The procedure selects a high energy node as the CH to route the data using the theory of the CAODV.

The exercise avails the use of NS2 platform to display the indices computed for a time frame of two hundred seconds when the network carries a data size of 3000 Kbps to reflect the efficiency of the proposed approach. The procedure extends to bring out the merits of CAODV in relation with three other routing patterns (Original AODV (OAODV), Improved AODV (IAODV) and Adaptive Cluster Based Routing Protocol (ACBRP)).

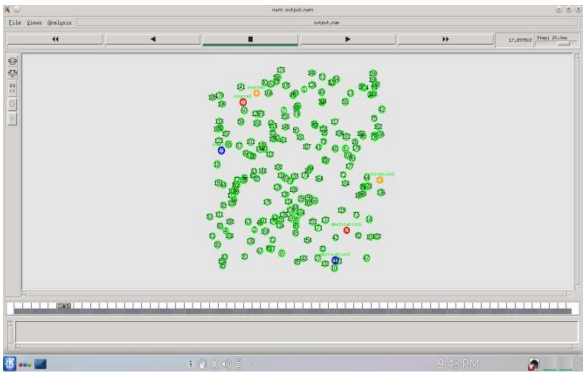

Figure2. Network Model

The number of packets transferred appears to rise for the four routing schemes with the highest increase over time and accompany it with minimum loss of packets for CAODV as seen from Figs.3 and 4 respectively. The graph plotted in Fig. 5 assuages the average throughput for CAODV over its counterparts to ensemble its benefits for nodes grouped with same hop counts.

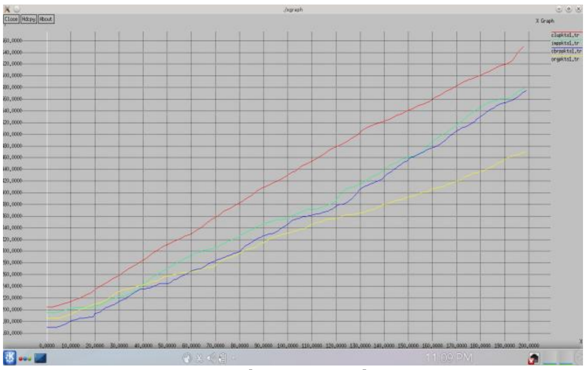
Figure3. Packets Received vs Time

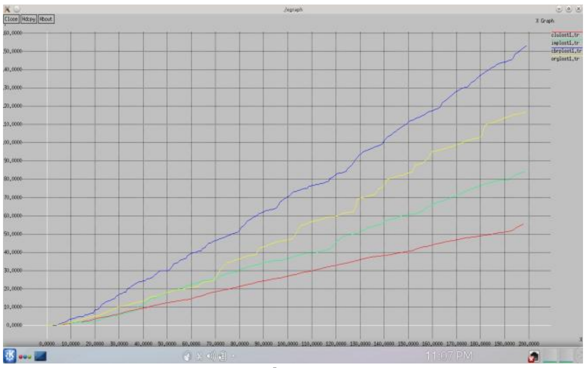
Figure4. Packet Loss vs Time

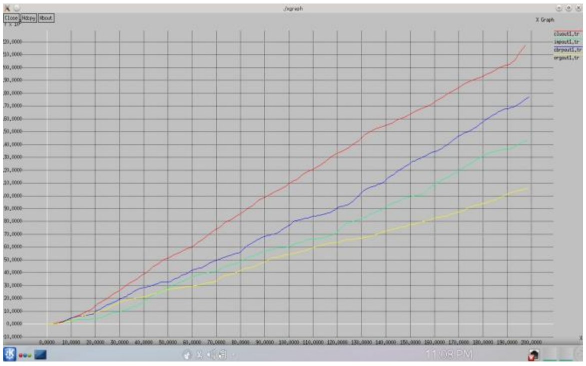
Figure5. Throughput vs Time

The variation of energy consumed with respect to time in Fig. 6 allows the CAODV to enjoy the energy efficient characteristic and leaves way to increase the network lifetime. The delay associated with the transmission of packets traced in Fig. 7 accrues to be the minimum for CAODV in relation with the three other schemes and favours a significant enhancement in network service.

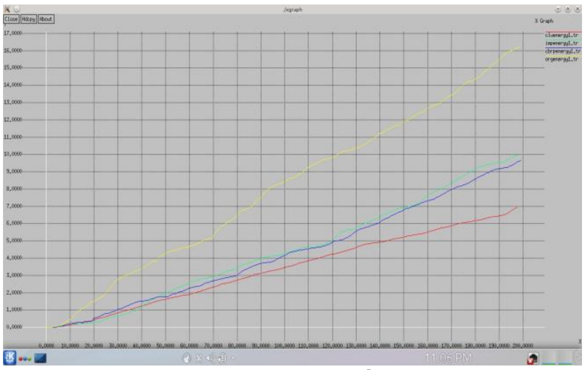
Figure6. Energy Consumed vs Time

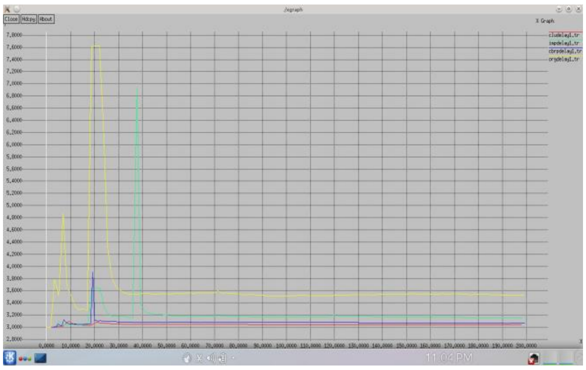
Figure7. Routing Delay vs Time

The thrust of the methodology extends to examine the suitability of the mechanism for large scale transmission. The bar charts drawn in Figs.8 through 14 establish the capability of the layered topology to offer the same level of performance for larger sizes of the packets transmitted. The CAODV carries the highest number of packets, incurs the lowest values for losses, provide the largest throughput in comparison with the others for increasing sizes of data rates as observed from Figs. 8, 9 and 10 respectively.

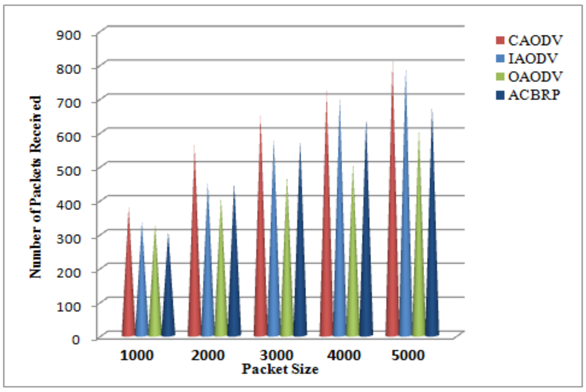

Figure8. Packets Received vs Packet Sizes

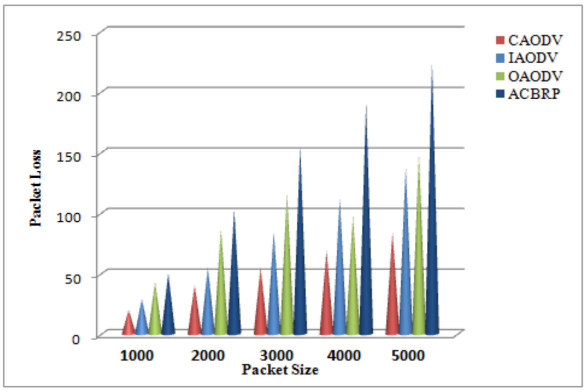

Figure9. Packet Loss vs. Packet Sizes

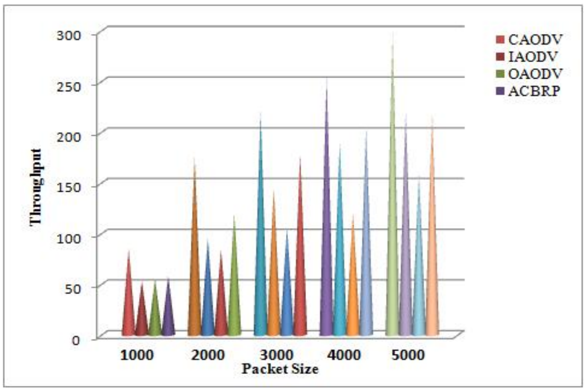

Figure10. Throughput vs Packet Sizes

Though the energy consumption of the network in Fig.11 seems to increase for higher sized packet transfer, still CAODV transfers the data with a lower delay for an increased packet size transmission as noticed using Fig.12 to claim the best network performance over the remaining schemes. The Energy*Delay metric expressed in Fig.13 computes to be the smallest for CAODV across a range of packet sizes and contributes to enhance the speed of transmission.

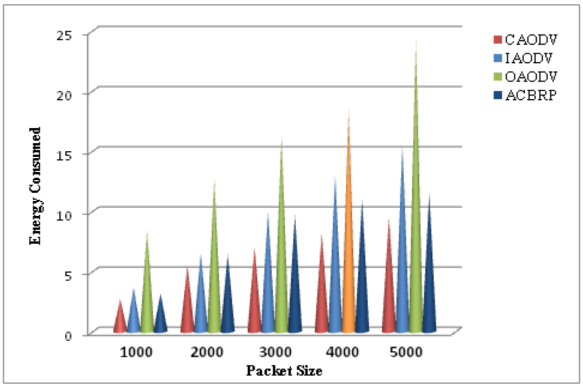

Figure11. Energy Consumed vs Packet Sizes

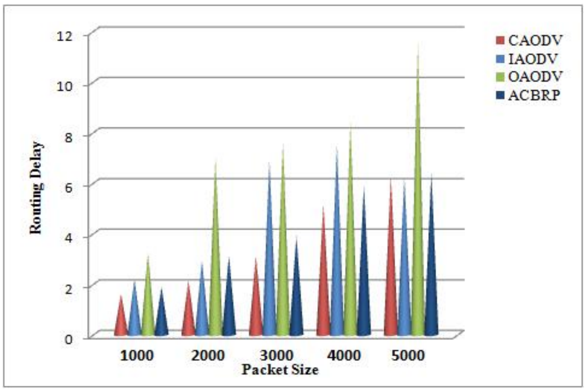

Figure12. Routing Delay vs. Packet Sizes

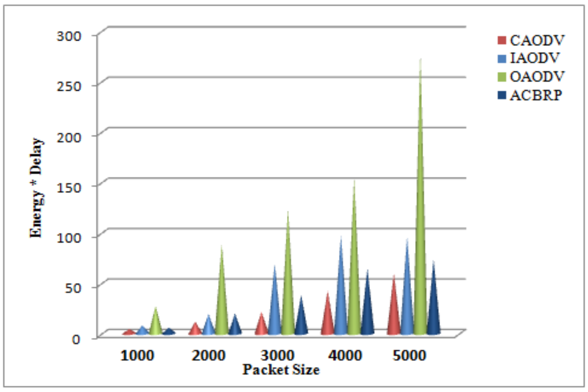

Figure13. Energy * Delay vs. Packet Sizes

The network Packet Delivery Ratio (PDR) bestowed as a line chart in Fig.14 follows to gradually decline for larger sized packets on account of the increased losses. However CAODV still yields the highest PDR to highlight its credibility among the other routing methodologies.

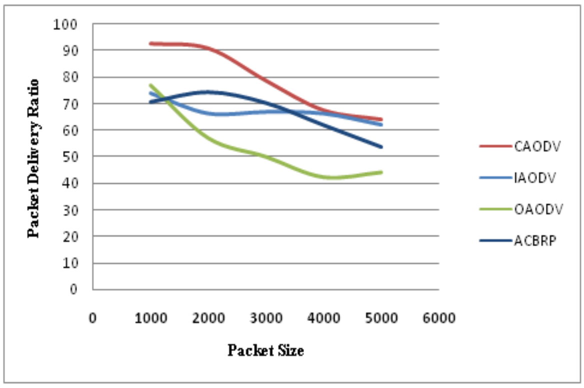

Figure14. Packet Delivery Ratio vs Packet Sizes

5. Conclusion

A two layered configuration with nodes of the same hop count in each layer has been evolved in a WSN. The role of a cluster based Ad-hoc On Demand Vector (CAODV) has been introduced and performance metrics displayed to support an increase in the life time of the network. An exhaustive comparative study has been fostered to exhibit the relative merits of the proposed routing pattern. The NS2 graphs have been drawn to establish the larger number of packets received, lower packet loss, higher throughput, smaller delay and minimum use of energy for transferring the data using CAODV. Besides its ability to outperform ACBRP has been centred to validate the use of a clustered concept with the philosophy of AODV and extricate still superior indices. The cognisance of the higher network PDR for CAODV over other schemes has been the highlight of the use of this methodology. The large scale data carrying capability of CAODV has been inscribed to reveal new frame works for data communication in the wireless world.

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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