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# Efficient Data Reporting Protocol for Wireless Sensor Networks

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**-------------------------------------------------------------ABSTRACT-------------------------------------------------------------**

**Wireless sensor networks (WSNs) are used for collection of data from the area of interest. WSNs deployment, application requirement and nature of phenomena have an effect on the generation of data. The data generated can be redundant and injection of redundant data into the network reduces the lifetime of energy constrained WSNs. In this paper, we propose anefficient data reporting protocol (EDRP)which filters the redundant data and thereby reduces the energy consumption of sensor nodes (SNs). EDRP can be tuned according to the application requirements. Simulation results show that significant energy is saved by our proposed scheme. Effect of two parameters (acceptable limit and *Check*) used by EDRP has also been analyzed. Simulation results show that acceptable limit greatly effects the energy consumption of the nodes.**

Keywords –**Data aggregation, Data reporting, Wireless sensor networks.**

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## 1. INTRODUCTION

Wireless sensor networks (WSNs) are now a day's gaining popularity and lot of research has been carried out in this field. WSNs are very different from other networks because of the constraints they have in terms of energy, hardware, bandwidth etc. WSNs are deployed for various diverse applications such as military applications, health care applications etc. and because of the challenges posed by the sensor networks, a great thrust is on the development of new protocols which cater to the need of various applications. Protocols proposed for WSNs and some of the adhoc network protocols which have been modified to adapt to WSNs mainly focus on reduction of energy consumption by SNsin order to improve the life time of WSNs.

The sensing nodes in WSNs generate a significant amount of redundant data in the network due to spatial-temporal correlations. Transmission of redundant data in a network causes a lot of wastage of energy hence reduces the network life time. More energy is consumed in transmission and reception of packets as compared to computation hence it is desirable to reduce the packet transmission. Similar data packets can be aggregated or combined to one thereby reducing the packets for transmission. Data aggregation reduces substantial amount of energy. Data aggregation is used by number of routing protocols for achieving energy efficiency. The amount of size by which a data can be reduced by aggregation depends on the application [1].

Our proposedprotocol namely efficient data reporting protocol(EDRP)has been designed to improvethe network lifetime by not transmitting the redundant data. We focus on a data gathering application, where a collection of SNs report sampled data to sink periodically. EDRP can be tuned for different applications by setting the application specific acceptable limit for the data to be reported. EDRP reduces the transmission of new data if the new data is similar to the one what aggregating node (AN) or SNhad reported earlier (or is within the acceptable range).ERDP makes use of buffers to store the previously sent and received data so that data transmission is reduced.

The rest of the paper has been organized as follows. Section 2 presents the literature review. In section 3 our proposed protocol (EDRP) has been explained. Simulation results and parameters used for analyzing EDRP are discussed in Section 4. The last section i.e. section 5 is of conclusion.

## 2. LITERATURE REVIEW

Data dissemination in WSNs is a process of transferring desired data from nodes sensing the event to sink. Data dissemination may involve some in-network processing of data items like data fusion, data aggregation. Limited energy of nodes has been the single major constraint affecting the design of a WSNs. Energy efficiency is an essential performance metric for sensor networks. Network life time of WSNs can be improved by finding optimal routes for query/data flow, devising efficient clustering schemes and by load balancing [2]. Authors in [3] [4] [5] [6] have proposed ways to achieve energy efficiency at MAC layer. Energy depletion in unbalanced way among SNs also reduces lifespan of a WSN and hence various methods have also been proposed to distribute load by rotating roles of cluster heads (CHs), distributing computations across network and coordinating various working modes (wake-up, sleep and sensing) of SNs [7] [8] [9] [10] [11].

In WSNs, aggregation techniques and routing protocols are interdependent. Routing protocol design takes into consideration data aggregation at some network nodes and accordingly decides packet routing mechanism. Data aggregation has significant impact on energy consumption and overall network efficiency. Data aggregation not only reduces network overheads, but also enhances network lifetime. Data aggregation can be done in two ways. The first one is to combine data from different sources to a single data unit. This reduces the size of information to be sent over the network. The second way of aggregation is, if data packets from different sources or nodes are combined in to one large packet. This results in significant reduction of network overheads [12]. Iterative channel adjustment data aggregation routing (ICADAR) algorithm[13] tackles the problem of co-channel interference as it leads to data retransmission due to collision. ICADAR uses greedy incremental tree (GIT) to find the efficient data aggregation tree and then assigns the channel.A practical energy-efficient protocol for aggregator selection (EPAS)[14]achieves the target number of aggregators as aggregation at multiple levels can further reduce energy consumption. EPAS has been extended to Hierarchical EPAS (HEPAS) to provide a multiple-level solution.

Hierarchical routing protocol (HRP)[15] is a cluster based protocol for increasing the life time of a sensor network. HRP first clusters the network and thereby constructs routing tree on CHs for sending the aggregated data to the base station. HRP remarkably extends network life time and the amount of data gathered. A clustering algorithm CODA[16, 17] divides the whole network into groups based on node's distance from the sink and the routing strategy. CODA removes the imbalance of energy depletion caused by different distances of nodes from the sink. Although CODA improves the life time of the network but it is not scalable as it relies on global information of node position.

In a tree-based network, sensor nodes are organized into a tree where data aggregation is performed at intermediate nodes along the tree and a concise representation of the data is transmitted to the root node. Tree-based data aggregation is suitable for applications which involve in-network data aggregation. An example application is radiation-level monitoring in a nuclear plant where the maximum value provides the most useful information for the safety of the plant. One of the main aspects of tree-based networks is the construction of an energy efficient data aggregation tree. Ding et al. [18] have proposed an energy-aware distributed heuristic (EADAT) to construct and maintain a data-aggregation tree in sensor networks. The algorithm is initiated by the sink which broadcasts a control message. The sink assumes the role of the root node in the aggregation tree. The disadvantages of EADAT are extensive use of timers and it requires the prior knowledge or support from a given tree root. Tan et al.[19] have proposed a power-efficient data gathering and aggregation protocol (PEDAP). The goal of PEDAP is to maximize the lifetime of the network in terms of number of rounds, where each round corresponds to aggregation of data transmitted from different sensor nodes to the sink. PEDAP is a minimum spanning tree-based protocol which improves the lifetime of the network even when the sink is inside the field. PEDAP minimizes the total energy expended in each communication round by computing a minimum spanning tree over the sensor network with link costs. In [20], Lee and Wong proposed E-Span algorithm, which is an energy-aware spanning tree algorithm. In E-span, the source node which has the highest residual energy is chosen as the root. Gupta et al. [21] have proposed an approach that relies on the construction of connected dominating sets. These sets consist of a small subset of nodes which form a connected backbone and whose positions are such that they can collect data from any point in the network. Nodes that do not belong to these sets are allowed to sleep when they do not have data to send. Some rotation of the nodes in the dominating set is recommended for energy balancing.

The authors in [22] analyzed the symmetric line network with different degrees of correlation among neighboring nodes. A model has been proposed to describe the spatial correlation in terms of joint entropy. Zhu et al. [23] have studied the impact of data correlation on the energy expenditure of data distribution protocols. They focus on various energy-aware data aggregation trees under different network conditions, such as node density, source density, source distribution, and data aggregation degree. In [24], a tree-based aggregation algorithm that exploits data correlation has been proposed. It is based on shallow Length Tree (SLT) that unifies the properties of Minimum Steiner Tree (MST) and Shortest Path Tree (SPT). Cristescuet al. [25] analyze aggregation properties of a tree structure that is based on an SPT of nodes close to the sink node, while nodes that are further away are connected to the leaves of the SPT via paths found by an approximation algorithm for the traveling salesman problem.Al-Karakiet al. [26] investigate which nodes in the network can be exploited as aggregation points for optimal performance. They present exact and approximate algorithms to find the minimum number of aggregation points in order to maximize the network lifetime. Algorithms use a fixed virtual wireless backbone that is built on top of the physical topology. Further, they study tradeoffs between energy savings and the potential delay involved in the data aggregation process.

Limited energy source, small bandwidth and typical deployment of large number of SNs pose many challenges to the design and management of WSNs. These constraints necessitate energy savings at all layers of networking protocol stack. Among many design challenges, energy efficient routing in WSNs is very vital due to several

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unique characteristics of WSNs that distinguish them from contemporary wireless ad hoc networks.

## 3. EFFICIENT DATA REPORTING PROTOCOL (EDRP)

EDRP has been designed to conserve the energy of the nodes and thus improve the life time of WSN. EDRP uses a time division multiple access(TDMA)-based medium access control(MAC) scheme where the time is divided into periodic MAC frames and each MAC frame is composed of multiple time slots. Each SN can transmit one packet in its allocated time slots so that collisions are avoided. EDRP can be implemented for any tree based or cluster based protocols for WSNs. EDRP reduces the transmission of redundant data as every node compares the new data with previously transmitted data (to its parent). Fig. 1 and Fig.2 show a simple tree structure and clustered network forWSNs. The data packets of $SN_{111}$ and $SN_{112}$ can be aggregated and transmitted as single packet by $AG_{11}$ (Fig.1). Likewise $AG_1$ can also transmit single packet by aggregating the two packets received from $AG_{11}$ and $AG_{12}$. The similar aggregation can be implemented in a clustered network where the CH will aggregate the datapackets received from SNs. In Fig.2 the various data packets of cluster1 can be aggregated to form a single packet by $CH_1$. $CH_6$ aggregates the aggregated data of $CH_5$and $CH_4$.The reduction in the number of packets transmitted not only reduces the energy consumption but also improves the life time of the network.

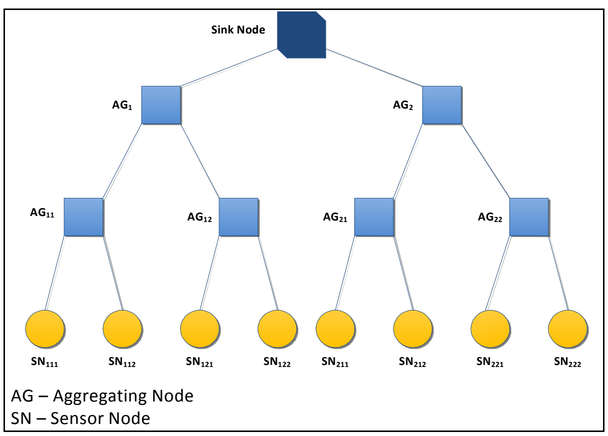


Figure 1:Tree structure of wireless sensor network.

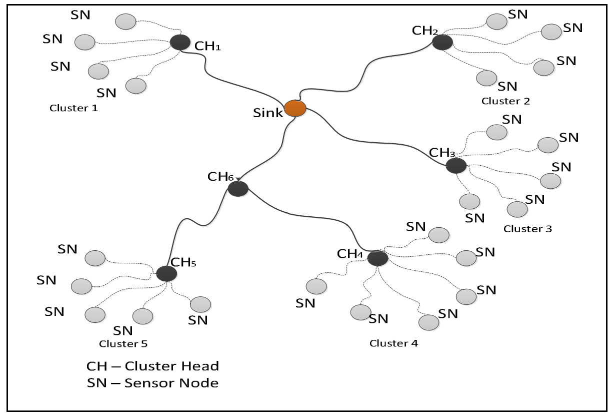


Figure 2:Cluster network for wireless sensor network.

### 3.1. Working of EDRP

The EDRP has been designed to reduce the transmissions by not transmitting the data which it had earlier been transmitted to AN. Consider a situations in which a child node has sensed similar data what it had sent previously i.e. if a child node say $SN_{111}$(Fig.1) had sensed $10^0$C temperature value at time $t_1$and had sent it to $AN_{11}$. Now at time $t_2$,$SN_{111}$ has sensed same temperature ($10^0$C) so transmitting the same data (reading) at $t_2$ (where $t_2>t_1$) will waste the energy of $SN_{111}$. $SN_{111}$ will not only conserve its energy but energy of $AN_{11}$ (reception energy) will also be conserved if $SN_{111}$ does not transmit its $t_2$ timereading. $SN_{111}$ can compare the new data with the previously transmitted data by storing the previously sent data in a buffer. The transmission can further be reduced by setting some acceptable range for the transmission of data packets. Acceptable range can be specified by setting an acceptable limit (which is application specific) in EDRP. Let us assume that if there is a change of $0.25^0$C in temperature between new reading and previously sent data (stored in the buffer)of $SN_{111}$. Such minor change if is within the acceptable range of an application (change need not be reported)then transmission energy of $SN_{111}$ can be conserved. $AN_{11}$which stores in its buffer the data it received from $SN_{111}$at $t_1$will assume already available data value of $SN_{111}$ for $t_2$ time.

ANs may also have similar aggregated data value (what it had previously sent) although data received from CNs is different. Let us assume an aggregating node has three (3) CNs and at time $t_1$, Nodes *N1*, *N2* and *N3*had sent temperature values $10^0$C, $12^0$C and $15^0$C respectively. CNs send at their respective data of time $t_2$i.e. $15^0$C, $9^0$C and $8^0$C. If aggregating function is f(x) = Max ($T_i$); (Where $T_i$ is the temperature value sent by CNs and i = 1, 2, 3 …..) then AN after applying aggregating function will send the maximum value of the temperature which will is $15^0$C at time $t_1$ and $t_2$. ANcan conserve its energy by not transmitting aggregated data at $t_2$. Similar to SN the transmission by AN can further be reduced by applying an acceptable limit for the aggregated data.

The parent node if does not receive any packet from its child node can be because of the two reasons, first one is that the child node has similar data to transmit and the second reason can be that the child node is a dead node. EDRP handles the two situations where parent node sends a transmission message ($Tx_{message}$) to its child node, which upon receiving this message has to transmit the data packet of similar reading also. The child node upon receiving $Tx_{message}$will transmit new data without comparing it with the previously sent data. The two algorithms of EDRP one for the child nodes and other for the parent nodes have been explained in subsection 3.2 and 3.3.EDRP can be implemented for reducing the data transmission for both tree as well as clustered WSNs.

The Scenario for the working of EDRP is shown in figure 3. The nodes $SN_{111}$and $SN_{112}$(Fig. 1) transmit data at time $t_1$to their parent ($AG_{11}$). Likewise $SN_{121}$ and $SN_{122}$ at $t_1$send data to $AG_{12}$. $AG_{11}$ and $AG_{12}$ transmit the aggregated data to their parent node ($AG_1$). At $t_2$only $SN_{111}$ and $SN_{122}$transmit data to their respective parent nodes, which are sending the aggregated data to their parent. At $t_3$since $AG_{11}$ has not received data from $SN_{112}$it sends a transmission message ($Tx_{message}$) to $SN_{112}$ to check whether the node is dead or alive. On receiving the message, $SN_{112}$ at $t_4$ has to send the message irrespective of whether it has sensed data ornew data is similar to the previous one. At $t_4$ since $AG_{11}$ has not received any data from $SN_{111}$ it sends a $Tx_{message}$to it. Similarly at $t_4$,$AG_1$has not received data packet from $AG_{11}$so it sends a $Tx_{message}$ to $AG_{11}$. At $t_5$, $SN_{111}$ sends data to $AG_{11}$ on receiving transmission message from $AG_{11}$ at $t_4$and $AG_{11}$ also sends a data packet to $AG_1$.

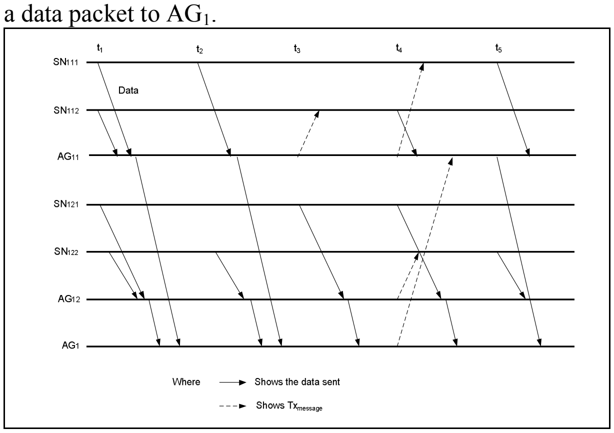


Figure 3: Scenario for the working of EDRP.

3.2. Algorithm 1: EDRP for Child node

The Algorithm 1 is for child nodes where the acceptable range for sensor reading can be set by setting the acceptable limit value i.e. $\delta_{CN}$. This value is application specific and it can be set to zero, where any change in the observed reading is to be reported by the SN. In case when it is set to zero the reduction in the transmission of redundant data will be less. The reduction in the transmission by SN depends on the acceptable limit $\delta_{CN}$. SN after sensing compares the present data with the previous data sent to its parent node. Previous data is stored in its buffer i.e.*Tx_BUFFER*. If the new data is not equal to the previous data and is not in the acceptable range, then it is transmitted and is stored in *Tx_BUFFER*. Nodes will transmit the data if they receive a transmission message ($Tx_{message}$) from its parent node irrespective of the data value.

### Pseudo code of Algorithm 1: EDRP for child node.

1. Set application specific value of $\delta_{CN}$. // $\delta_{CN}$ is the application specific acceptable limit.
2. **int***Tx_BUFFER* // Buffer for storing the transmitted data.
3. SN senses environment.
4. ***if***(event is detected) && ($Tx_{message}$ not received) ***then begin***
5. ***if***( *New_Data* == *Tx_BUFFER*) || ( *New_Data* == *Tx_BUFFER* ± $\delta_{CN}$) ***then begin***
6. Go to Step 2.
7. ***else***(*Tx_BUFFER*= *New_Data*)
8. Transmit *New_Data* //Transmit *New_Data* to parent node.
9. ***endif***
10. ***elseif***(event is detected) &&($Tx_{message}$received)***begin***
11. (*Tx_BUFFER*= *New_Data*)
12. Transmit *New_Data*// Transmit *New_Data* to parent node.
13. ***endif***
14. ***endif***

3.3. Algorithm 2: EDRP for aggregating node

Acceptable range for the ANs can be set by setting the acceptable limit ($\delta_{AG}$). Acceptable range of CNs can be different than ANs.EDRP makes use of two buffers at ANs.Buffer *Tx_BUFFER*stores the previously transmitted aggregated data by AN. Second buffer *Rx_BUFFER[ ]* stores the data received from the CNs. ANs apply aggregating function on the data of their *Rx_BUFFER[ ]*. The aggregated data value is then compared with the previously sent aggregated data stored in *Tx_BUFFER*. If the new aggregated data value is same or within acceptable range, then it is not transmitted. The acceptable range can be set so that any change in the data is reported, by setting the value of acceptable limit $\delta_{AG}$ to zero. If AN, receives data from some of its child nodes, then it uses the previous data value (stored in *Rx_BUFFER [ ]*) of the child nodes, who did not send data. The new data from some of the nodes is stored in *Rx_BUFFER[ ]*and aggregating function is the applied on the dataof *Rx_BUFFER[ ]*.

There will be no transmission from child nodes to parent nodes if their new data is similar to previously sent data. An application specific variable *Check* is used by EDRP, so that after elapse of application specific interval (set by C*heck*); the child has to transmit a data packet irrespective of the value of that data reading. The parent node sends a transmission message ($Tx_{message}$) message to their child nodesto transmit data in their next transmission slot.

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**Pseudo code of Algorithm 2: EDRP for aggregating node.**

1. Set application specific value of $\delta_{AG}$ and *Check*. // $\delta_{AG}$ is the application specificacceptable limit and *Check* is application specific value for generation of TXMESSAGE message to child node
2. **Initialize** :
3. **int***Tx_BUFFER* // Buffer storing the aggregated data sent to Parent node
4. **int***No_of_CHILDNODES* // Number of child nodes of aggregating node
5. **int***Rx_BUFFER[]* // Stores data received from CNs
6. **int***Check* // Application specific set for sending $Tx_{message}$ to child node
7. **int***Counter* = 0 // *Counter* initialized to zero
8. Aggregating node is receiving.
9. ***if***(Received from child nodes)&&($Tx_{message}$not Received)***then begin***
10. ***for***( i = 1 to i = *No_of_CHILDNODES*)***begin***
11. *Rx_BUFFER[ No_of_CHILDNODES] =*
    $New\_Data_i$
    // $New\_Data_i$ is data of child nodes where
    i = 1to*No_of_CHILDNODES*
12. Apply aggregating function on data storedin
    $Rx\_BUFFER_{AG}[\,]$
13. ***if***($New\_Data_{AG}$==*Tx_BUFFER*) ||
    ($New\_Data_{AG}$==*Tx_BUFFER* $\pm\delta_{AG}$ )
14. Go to step 8.
15. ***else*** (*Tx_BUFFER*= $New\_Data_{AG}$)
16. Transmit $New\_Data_{AG}$
17. ***endif***
18. ***endfor***
19. ***elseif*** (Received from all Child Nodes)&&($Tx_{message}$ received)***then begin***
20. ***for***(i = 1 to i = *No_of_CHILDNODES*)***begin***
21. *Rx_BUFFER[No_of_CHILDNODES] =*
    $New\_Data_i$
    // $New\_Data_i$ is data of
    child nodes where i = 1 to *No_of_CHILDNODES*
22. Apply aggregating function on data stored in *Rx_BUFFER[ ]*
23. (*Tx_BUFFER*= $New\_Data_{AG}$)
24. Transmit $New\_Data_{AG}$
25. ***endfor***
26. ***endif***
27. ***if*** (not received from child nodes)&&($Tx_{message}$not received)&&(Counter<*Check*) ***then begin***
28. ++ *Counter*
29. Go to step 8.
30. ***else***
29. Send $Tx_{message}$
31. ***endif***
32. ***if***(not received from child nodes)&&($Tx_{message}$ received)***then begin***
33. ++ *Counter*
34. Transmit Data of *Tx_BUFFER*
35. ***endif***

3.4. Analytical model for EDRP

Suppose there are $N$ numbers of nodes and they form $L$ clusters. Then the total number of nodes in one cluster will be given by $N/L$. Let $N/L = K$, where $K$ are the total number of nodes in one cluster. Let the probability of change in data be given by $p$ that is also the probability of transmission in case of EDRP. Then $1\text{-}p$ is the probability of not changing data or it is the probability of nodes not transmitting. Let us assume that $K_1$ nodes are transmitting out the $K$ nodes in a cluster, so $K - K_1 = K_2$, where $K_2$ are the number of nodes not transmitting. Then for each cluster, according to EDRP at time say $t_1$ either one of the following three cases can be true.

**Case 1: When no node transmits.**

When nonodes transmit then the probability of transmission is given by (1):

$$^{K}C_0\, q^K,\ \text{where} K_1 = 0. \quad (1)$$

**Case 2: When all nodes transmit.**

When all nodes transmit then the probability of transmission is given by (2):

$$^{K}C_k p^K,\ \text{where} K_1 = K. \quad (2)$$

**Case 3: When some nodes transmit.**

When $K_1$ nodes are transmitting out of $K$ nodes in a cluster, the probability of transmission is given by (3):

$$^{K}C_{k_1}\, p^{k_1} q^{k-k_1} \quad (3)$$

Rewriting (3) as (4):

$$\frac{K!}{K_1!(K-K_1)!} \quad (4)$$

Applying DeMoivre Laplace transformation on (4) we get (5):

$$\frac{1}{\sqrt{2\Pi Kpq}}\left(e^{-(k_1-Kp)^2/2Kpq}\right) \quad (5)$$

Subject to following conditions:

1. $Kpq >> 1$
2. $|K_1 - Kp| << \sqrt{Kpq}$

The equation (5) will satisfy if $K$ is significantly large.

The standard Gaussian distribution function is given by the (6):

$$\frac{1}{\sqrt{2\Pi\sigma^2}} e(-(x-\mu)^2/2\sigma^2) \quad (6)$$

Hence (5) is equivalent to (6) where:

$X = K_1,$
$\sigma^2 = npq$ and
$\mu = np$

Let us assume that $K_1, K_2, K3 \dots K_L$ is the number of nodes transmitting in $L$ clusters in a network. The total nodes in a network that can transmit are $N-1$ as one node is root node or sink and will not transmit. The combined transmitting probability in a network is given by (7):

$$\binom{N-1}{K_1 K_2 \dots\dots K_L} p_1^{K_1} p_2^{K_2} \dots\dots p_L^{K_L} \quad (7)$$

Where $P_1$, $P2 \dots P_L$ are probability of transmission for each cluster.

## 4.SIMULATION AND RESULTS

We have considered a clustered WSN where nodes are randomly deployed with single sink. Each SN is capable of sensing and transmitting data packet to its CH. A time division multiple access(TDMA)-based medium access control(MAC) scheme has been employed where the time is divided into periodic MAC frames and each MAC frame is composed of multiple time slots. Each SNtransmits one packet in its allocated time slots in such a way that no collision occurs.

The proposed protocol has been simulated in Omnet++ for variable number of nodes for evaluating its performance and comparing it with the other protocols. It has been assumed that all the nodes have 5J of energy. The constant radio parameters i.e. $\alpha_{11}$, $\alpha_{12}$ and $\alpha_2$are chosen with typical values as $\alpha_{11}$ = 50nJ/bit, $\alpha_{12}$= 50nJ/bit, and $\alpha_2$ = 10 pJ/bit/m$^2$ ($n$ = 2) or 0.0013 pJ/bit/m$^4$ ($n$= 4) [26].The energy model adopted in [26] has been adopted with slight modifications for simulation. The various notations used for energy equations are given in Table 1. The energy consumed by a node to transmit data packet to distance $(d)$meters is $P_{tx}(d)$, where $P_{tx}(d) = (\alpha_{11} + \alpha_2 d^n)\, r$. Energy consumption by a node to receive data packet is denoted by $P_{rx}$, where $P_{rx} = \alpha_{12} r$. The computational energy has been taken into consideration while evaluating the performance. The energy consumption for executing 3000 instructions is taken equivalent to energy consumed for transmitting a bit for 100 m. We have considered a cluster of $N$ nodes having a radius of $R$ withdata transmission rate$r$ and the distance between two CHs is $D$, the expected energy consumption per second of such a cluster is given by (8):

$$E\,[P_{cluster}] = (N\text{-}1)[\alpha_{12} + \alpha_2(2R^n/n+2)r + (\alpha_{11} + \alpha_2 D^n)r \quad (8)$$

The simulation parameters chosen for calculating the results are presented in Table2.

Table 1: Notations and Definitions

| Notation | Definition |
|---|---|
| $\alpha_{11}$ | Power to run transmitter circuitry |
| $\alpha_{12}$ | Power to run receiver circuitry |
| $\alpha_2$ | Power for the transmit amplifier to achieve an acceptable signal to noise ratio |
| $n$ | Path loss exponent that depends on environment. |
| $r$ | Number of bits transmitted per second |
| $N$ | Total number of sensor nodes in a network |
| $R$ | Area radius of a cluster |
| $N$ | Number of sensor nodes in a cluster |

Table 2: Simulation Parameters

| Parameter | Value |
|---|---|
| Number of nodes($N$) | 100,200,300,400 and 500 |
| Initial energy per node | 5J |
| Path loss exponent($n$) | 2,4 |
| Size of Data Packet | 500 bits |
| Size of control Packet | 10 bits |
| Data transmission rate | 500 bits/second |
| Acceptable limit for sensing nodes($\delta_{CN}$) | 0.25,0.5, 0.75,1 and 1.25 |
| Acceptable limit for aggregating nodes($\delta_{AG}$) | 0.25,0.5, 0.75,1 and 1.25 |

The average energy consumed per node for different acceptable limits of EDRP and HRP is shown in Fig. 4. The energy consumption in case of HRP is more as compared to EDRP because EDRP reduces the transmission of redundant data. The energy consumption of EDRP is more in case when the acceptable limit is less. This is because of the fact that there are more transmissions in case the acceptable limit is less; hence by increasing the acceptable limit energy can be conserved. Life time of the network as well as node energy can be improved by increasing the acceptable limit. The nodes can be fine tuned according to various application requirements and their acceptable limit can be set according to the application specific requirements.

Fig. 5 shows the ratio of number of packets received at the sink to the total number of packets generated for variable number of nodes(100-500) for various acceptable limits i.e 0.25, 0.5 and 0.75. The results show that as the acceptable limit is increased the ratio decreases hence the number of transmitted data packets are reduced which increases the life time of the network and reduces the energy consumption of the nodes. Results of Fig. 4 and Fig.5 show that the acceptable limit has an effect on the life time of the network and on the energy consumption of the nodes. EDRP can be tuned according to application requirements but if acceptable limit is reduced then the energy consumption of the nodes will be more.

Fig.6 shows the graph between the number of rounds taken for first node to die for variable number of nodes with different acceptable limits of EDRP. Fig. 6 shows that as the accepatble limit is increased it takes more number of rounds for first node to die. Results also show that as the nodes are increased it takes less rounds for first node to die. As the nodes are increased or acceptable limit is reduced the data packets transmitted will be more hence more energy will be consumed.

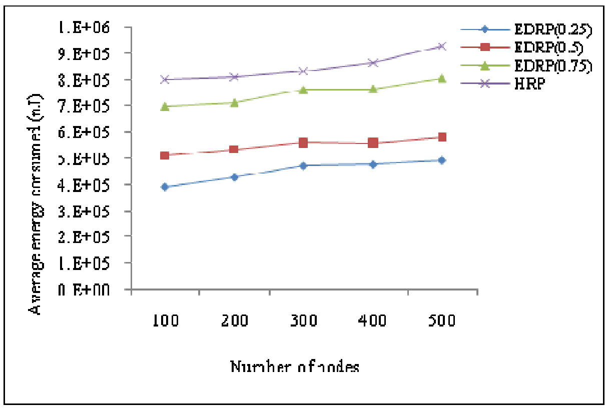


Figure 4: Average energy consumed per node.

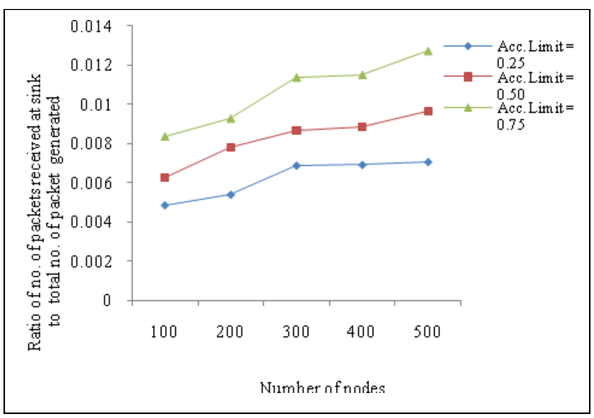


Figure5: Ratio of number of packets received at sink to total number of packet generated for EDRP.

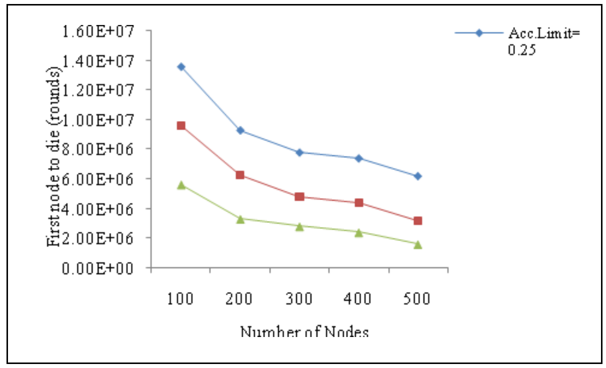


Figure6: First node to die (rounds) Vs Number of nodes.

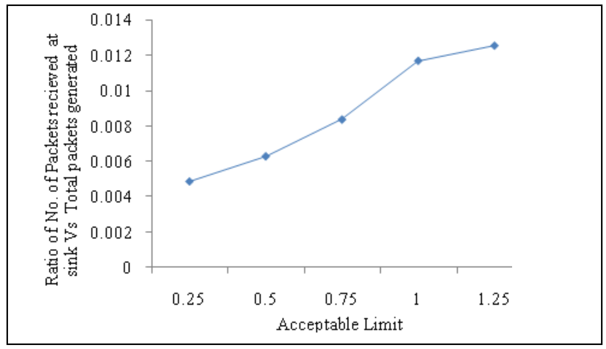


Figure7: Effect of acceptable limit on EDRP.

Fig. 7, shows the effect of acceptable limit on the ratio of number of packets received at sink versus the total number of packets generated. The results were obtained for network of hundred nodes. As the acceptable limit is increased this ratio decreases thus verifying the results of Fig. 5 and Fig. 6.

Fig. 8 shows the effect of *Check* on the energy consumption by the nodes for EDRP. The results were obtained for network consisting of hundred nodes. Results for average energy consumption per node for various values of *Check*show that as the value of *Check* increases the average energy consumed per node decreases. This is because if the value of *Check* is less then more transmission messages ($Tx_{message}$) and data packets will be transmitted therefore energy consumption of the nodes is more.

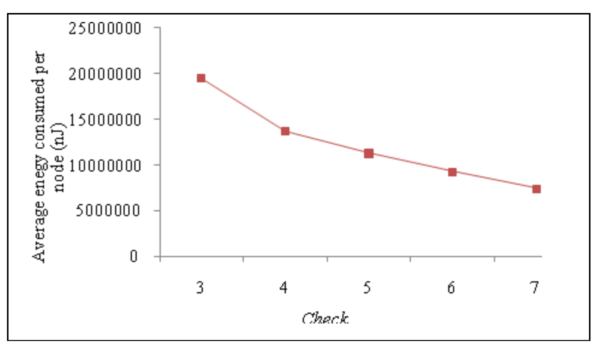


Figure8: Effect of *Check* on average energy consumption per node for EDRP.

## 6. Conclusion

Injecting redundant data into the network has a great impact on the energy consumption of sensor nodes. Our proposed scheme (EDRP) significantly reducestransmission of redundant data by sensor nodes as well as the aggregating nodes. EDRP disseminatesdata by sensor nodes or cluster heads (aggregating node) only after filtering it against the acceptable limit. Acceptable limit is an application specific limit, which can be set according to the various application requirements. The acceptable limit of aggregating nodes and sensing nodes can be set differently. This parameter has an effect on the data packets being injected in the network. Simulation results show that as the value of acceptable limit increases, the data transmission is reduced. Another parameter that can be set according to application requirement is C*heck*. Results show that as the value of check is reduced the transmission of control and data packets is increased hence energy consumption of nodes is increased.

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