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A Transmission Control Protocol for Wireless Sensor Network

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Abstract: Wireless Sensor Network (WSN) is a hot area of research which is useful in countless applications in various fields of engineering and technology. In WSN wireless nodes are dispersed in a well confined area, and most of the times are static once they are deployed. These nodes are battery operated and their energy goes down as they transmit beacon or informative packets. In past many routing protocols are proposed which tries to minimize the energy dissipation by using various approaches. Till date in proposed protocols information is transmitted in each round, however in many applications such frequent information/update is not desirable, therefore to restrict transfer of packets in each round in this paper a transmission control protocol is proposed, where by varying the load, transfer of packets can be controlled, and this mechanism reduces the dissipation of energy and thus improves, stability period, network lifetime and throughput. The performance evaluation of the proposed scheme is done using MATLAB software and keys features of proposed protocol are highlighted along with simulation results.

Keywords: Wireless Sensor Networks, Load, Radio Model and Throughput.

1. Introduction

With the advancement in technology wired communication is becoming wireless. Wireless communication is sometimes runs through sensors and defined as wireless sensor network. Wireless sensor network is created using battery operated nodes known as motes. Thus it becomes important to preserve battery power, and to do so various protocols are proposed in past. These protocols can be used in various applications like: military, agriculture, humidity, temperature etc [1].

In WSNs different nodes sensed data and the gathered information is send to the sink. These sensor nodes can be deployed randomly or in pre-defined fashion. Moreover, nodes can be mobile or stationary [2-4]. The randomly deployed nodes are generally distributed uniformly over the entire field. In sensor nodes energy is dissipated in sensing, transmission and reception. In WSN practically it is not possible to replace batteries once nodes are deployed. Thus to save battery power various routing protocols are proposed.

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a. *Proactive Routing Protocols:* In these types of protocols nodes keeps on sensing, and whenever data is available for transmission, then turn on their transmitter and transmit data. These protocols are suitable where continuous report is desirable.
b. *Reactive Routing Protocols:* in these types of protocols nodes continuous sense data and information is send whenever a significant change is observed in sensed value.

In routing protocols for energy saving clustering is used (Fig, 1). In clustering mechanism, nodes in a cluster transmit data to cluster head. The election of cluster head is either dependent of residual energy or based on some probabilistic function [2-4].

There are many applications, of WSN where frequent update of information may or may not be desirable. For example in agricultural applications where dampness of soil needs to be updated once in a day, however it may vary season to season. Similarly depending on the patient conditions update of record may be desirable on hour/day basis. To control the information transfer on the basis of applications, this paper proposes a load based transfer of packets towards the sink.

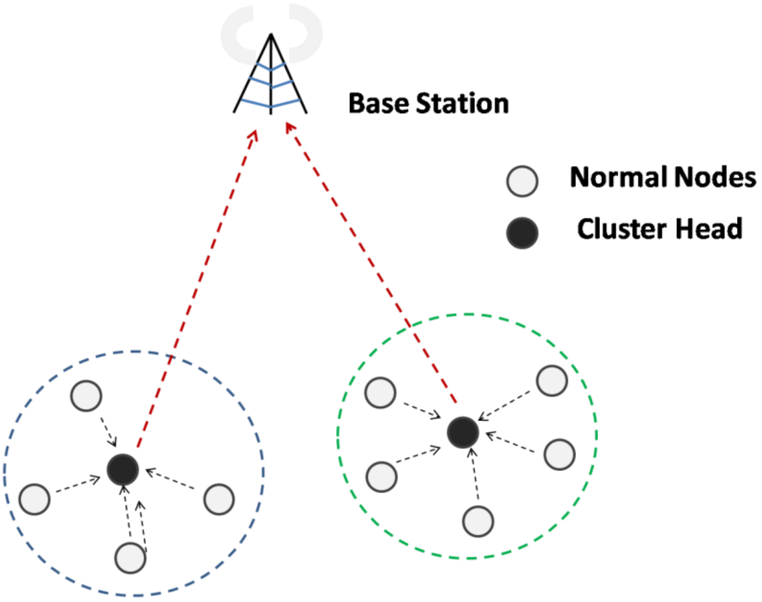

Fig. 1- Clustering mechanism and information transfer to BS.

2. Related Work

In this section, some of the notable routing protocols are discussed. For each routing protocol basic functionality is discussed along with their pros and cons.

2.1 LEACH

LEACH is the most widely used and aspiring protocol in WSN [4]. It can be explained as a blend of a multi-hop routing and cluster-based architecture. The word cluster-based can be described with the help of the fact that sensors that uses the functions of LEACH protocol are depend on cluster members and cluster heads. For inter-cluster communication, multi-hop routing is used along with cluster heads and base stations. It is clearly shown by the simulation results that less energy is consumed by multi-hop routing in comparison to the direct transmission [4].

It is already been mentioned that wireless sensors, sense the data, collect them and after this send it to the base station from a remote area by making use of the radio transmission plan as a medium of communication.

While sending the collected data by the sensors to the base station, a number of problems take place like data aggregation and data collision. LEACH is very effectively worked to decrease the data aggregation problems by making use of a local data fusion which carries out a compression of the data measure which is done by the cluster head prior to sending it to the base station. A self-organized network is formed by all sensors. This is accomplished by sharing a cluster head role at least once. The major responsibility for sending the data to the base station is of cluster head. It attempts to create the balance of energy dissipation within the network and improves the life time of the network by enhancing the life time of the sensors [4].

The scalability of LEACH is high because nodes can conveniently deal with the changes such as deployments of new node in the network and they can begin the process as cluster members by making use of the signals transferred by cluster heads. With the formation of clusters, it becomes more energy conservative as the responsibility of transferring data is of only cluster heads and each node adhere randomized rotation in order to create cluster head. It does not consist of quality of service feature due to limited resource such as limited processing which is performed with quite low memory buffer size. Apart from these, it also has an erratic traffic pattern because in the network all nodes continue to change the regions of cluster.

2.2 PEGASIS

In PEGASIS using chain data is transmitted, thus delay is more in this protocol. In this protocol a distant node has to suffer a lot, as data will pass through complete chain before receiving at the base station. In PEGASIS generation of chain is very important, thus this protocol has good awareness of energy while in developing chain structure [5]. This protocol consumes lesser energy in chain formation as compared to LEACH clustering formation. In this protocol instability is a major issue in case of node and link failure, thus a large loss of data can incur.

2.3 SPIN

SPIN is a compromised protocol as it tries to send information to base station via negotiation with other nodes. In this protocol latency is average [6]. Scaling of nodes using this protocol is not easy, as due to constraint nature of the protocol node having lesser energy do not respond to newly added node. In this protocol data overhead is low as few nodes only participate in information transfer. Quality of service is low, thus redundant data may be found in the network.

2.4 SPEED

SPPED is the one of the finest routing protocols. In this protocol latency is low. In SPEED network is managed in such a way that congestion does not happen, thus it improves the packet transfer to the sink [7]. This protocol is very efficient and provide good throughput with lesser average delay.

2.5 SEP

In this protocol, nodes heterogeneity is studied, where two types of nodes normal and advance are considered. The energy of advance nodes is more in comparison to normal nodes. This protocol investigates the performance in terms of stability period, network life time and throughput [8]. This protocol also uses clustering mechanism for packet transfer to sink.

In many applications continuous information/report is not desirable, therefore a mechanism is desired which can control the continuous transfer of packets. The proposed protocol tries to minimize the continuous transmission of packets by using the concept of load. This paper, presents a transmission control protocol where frequent transfer of information is controlled using the concept of load, and load itself depends on the how frequent update are desirable. The load will be defined by the doctor and it will depend on how often he requires reports update, let say if load is 0.1, means on an average after 10 rounds he is seeking the patient information. This one round can be of some minutes or of some days, depending on report requirements. The doctor will send it request to the server that how often he requires updates of report, depending on updation time server will send information to base station and base station will transfer load to each node, as each node is equipped with tiny OS, where a random number is generated and if randomly generated number is lesser than the pre-defined load than information will be transmitted otherwise it will b aborted.

3. Proposed Models

In the beginning of the network cluster head transmit a value which is defined as load to each node. Thereafter in the beginning of each round each node generates a random number between 0 and 1 and if its value is lesser than load then node turn on its transmitter and transmit. This process continues till load changes, if load changes, cluster head again broadcast new load to each node, and from next round onwards transmission takes place using the re-defined load.

Algorithm : Proposed Protocol

```
Routing Phase
For normal node, intermediate and advance nodes
If (ro<= load, ro is a random number [0,1]
Election of cluster head
Calculation of Energy dissipated
if (d<d0)
    Calculate energy dissipation using equation 6
  else
    Calculate energy dissipation using equation 6
end
 else
 Do nothing
 end
```

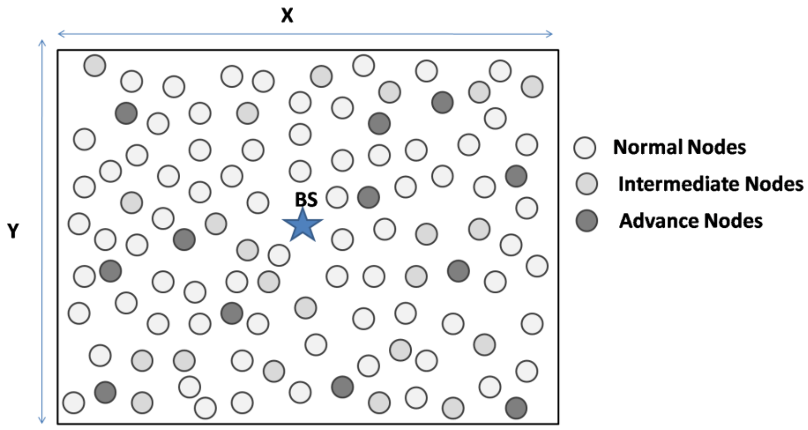

Fig. 2 - Distribution of nodes in square field

In case of load 1, network behaves like a normal WSN system, where in each round transmission takes place. The concept of load increases the time gap among the packets transferred to sink. In simple language if load is '0.2' than in each '10' rounds only in '2' rounds packets will be transferred to sink. The advantages of the following mechanism are as under:

1. In this process transmission is not done frequently, so energy consumption is much lesser to proactive networks.

2. At time of cluster change, values of load and attribute (or desired values) are transmitted afresh and so, user can decide how often to sense and what parameters to be sensed according to the defined load.
3. Attributes can be changed depending on requirement, as attributes are broadcasted at the cluster change time.
4. By varying load transmission of packet can be controlled.

In the proposed protocols three types of nodes are considered based on the energy of nodes: normal, intermediate and advance are considered. These nodes are randomly distributed over the considered area as shown in Fig. 2. Considering the energy of normal nodes as E_0, and the energy of intermediate nodes as $E_0(1+\beta)$ while the energy of advance nodes is $E_0(1+\alpha)$ where $\beta < \alpha$.

Furthermore it is also assumed that total number of nodes as n and fraction of total nodes which is intermediate node is q and advanced nodes fraction as r. So normal nodes are $(n-q-r)$.
Therefore, the total energy is

$$(n-q-r)E_0 + nqE_0(1+\beta) + nrE_0(1+\alpha) = nE_0(1+r\alpha+q\beta)$$

The optimal probability of selecting cluster head fore normal, intermediate and advance nodes are given by

$$p_{nor} = \frac{P_{opt}}{(1+r\alpha+q\beta)},\ p_{\text{int}} = \frac{P_{opt}(1+\beta)}{(1+r\alpha+q\beta)}\ \text{and}\ p_{adv} = \frac{P_{opt}(1+\alpha)}{(1+r\alpha+q\beta)}.$$

where, P_{opt} is the optimal probability of each node to become CH.
To become cluster head each node generates a random number and if the generated number is less than threshold then node becomes cluster head. The threshold values for normal, intermediate and advance nodes are given by

$$T_{nor} = \begin{cases} \dfrac{p_{nor}}{1-p_{nor}\left[r.\text{mod}\dfrac{1}{p_{nor}}\right]} & \text{if } n_{nor} \in G_1 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

$$T_{\text{int}} = \begin{cases} \dfrac{p_{\text{int}}}{1-p_{\text{int}}\left[r.\text{mod}\dfrac{1}{p_{\text{int}}}\right]} & \text{if } n_{\text{int}} \in G_2 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

$$T_{adv} = \begin{cases} \dfrac{p_{adv}}{1-p_{adv}\left[r.\text{mod}\dfrac{1}{p_{adv}}\right]} & \text{if } n_{adv} \in G_3 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

respectively. In above, *Gi* denotes the set of (normal, intermediate and advanced) nodes which has not become cluster head in past. Average number of cluster head in a round will be given by

$$n(1-q-r)\,p_{nor} + nqp_{\text{int}} + nrp_{adv} = np_{opt} \quad (4)$$

$$(1-q-r)\,p_{nor} + qp_{\text{int}} + rp_{adv} = p_{opt} \quad (5)$$

4. Radio Model

This paper consider first order radio model as discussed in [9]. If the distance between a transmitter and the receiver is less than a pre-defined threshold than free space (*fs*) model is considered, else muti-path (*mp*) is used (Fig. 3). The consumed amplifier energy (*Eamp*) is a function of distance and it is also dependent on threshold distance. The expression for amplifier energy is given by

$$E_{amp} = \begin{cases} E_{fs}d^2 & \text{if } d < d_0 \\ E_{mp}d^4 & \text{if } d \geq d_0 \end{cases} \quad (6)$$

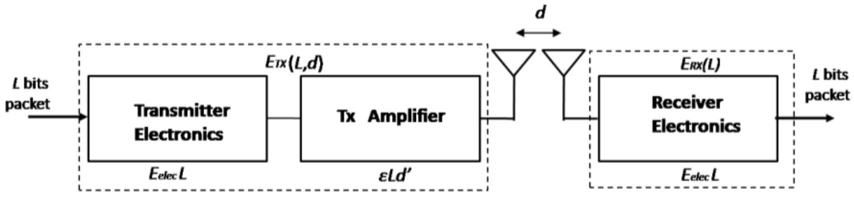

Fig. 3- First order radio model

The threshold distance is evaluated by equating free space and multi-path energy equations

$$E_{fs}d_0^2 = E_{mp}d_0^4 \Rightarrow d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \tag{7}$$

If a node transmit an *L* bits message over distance *d*, then transmission energy will be given by

$$E_{TX}(L,d) = \begin{cases} L.E_{elec} + L.E_{fs}.d^2 & \text{if } d < d_0 \\ L.E_{elec} + L.E_{mp}.d^4 & \text{if } d \geq d_0 \end{cases} \tag{8}$$

The energy for reception is (9)

$$E_{RX}(L) = LE_{elec}$$

Energy Consumption Model

Considering a field of dimension X×Y, where *n* nodes are uniformly distributed and further assuming that *k* number of clusters in the topology. Thus without loss of generality it can be assume that there will be *n*/*k* nodes per cluster. One of these nodes will be cluster head so left over (*n*/*k* -1) nodes will be normal nodes.

It can be assume that nodes within a cluster will use free space model to transfer information to cluster head (CH).

Energy consumed during normal node transmission is

$$E_{non-CH} = LE_{elec} + LE_{fs}d_{CH}^2 \tag{10}$$

Energy consumed by cluster head during *L* bit message transmission is

$$E_{CH} = \left(\frac{n}{k} - 1\right)LE_{elec} + \frac{n}{k}LE_{DA} + E_{TX}(L, d) \tag{11}$$

E_{DA} is the energy used in data aggregation. The energy dissipated by a single cluster is given by

$$E_{Cluster} = \left(\frac{n}{k} - 1\right)E_{non-CH} + E_{CH} \tag{12}$$

Thus the energy dissipated in a single round by all the cluster is

$$E_D = \sum_{i=1}^{k} E_{Cluster}(i) \tag{13}$$

Therefore, in order to save energy, un-necessary transmission of information from nodes to cluster head needs to be reduced.

Table 1 - Network parameters

Parameters	Value
E_0	0.5 Joule
E_{elec}	5.0 nJ/bit
E_{fs}	10.0pJ/bit/m^2
E_{amp}	1.3 *f*J/bit/m^4
E_{DA}	5.0 pJ/bit
Packet Size	4000 bits
α	1
β	0.5

5. Simulation Results and Analysis

Simulation is done using MATLAB software. In the simulation a field of dimension 100m×100m is considered. Total numbers of nodes considered to be 100out of which 10 nodes are advance nodes 30 nodes are intermediate nodes and rest 60 nodes are normal nodes. The sink is at position (50, 50) m. The energy of normal nodes of 0.5 J, for intermediate nodes 0.75 J and for advanced nodes 1.0 J. Simulation is run from 5000 to 15000 rounds on various loads.

In Fig. 4, alive nodes vs. rounds are plotted under different loads. From the figure it can be concluded that at the lower load nodes remain alive for longer duration and as the load increase due to the more transmission of packets more energy depletes thus node dies earlier. It is also observable that the number of rounds till first and last node dies is much more at lower loads. Thus, both stability period and network life time is more at lower loads. However, at the load increases, gap among the curve reduces and performance starts to converse. Thus, using the concept of loads transmission of packets is controlled and nodes remain alive for more number of rounds.

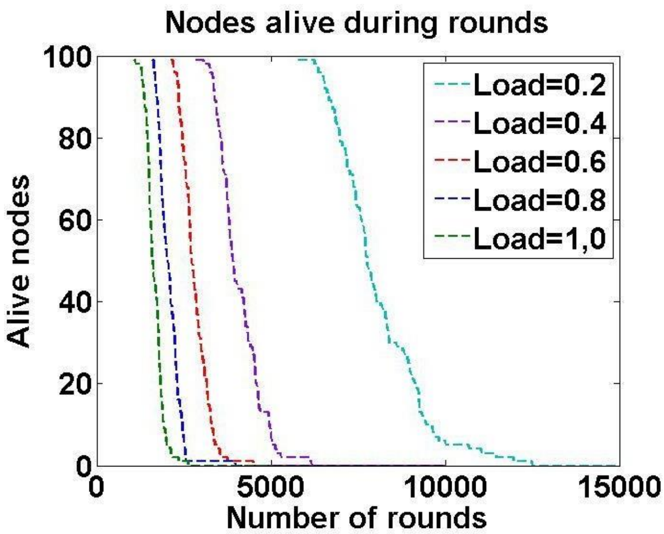

Fig. 4 - Alive nodes vs. rounds under various loading conditions

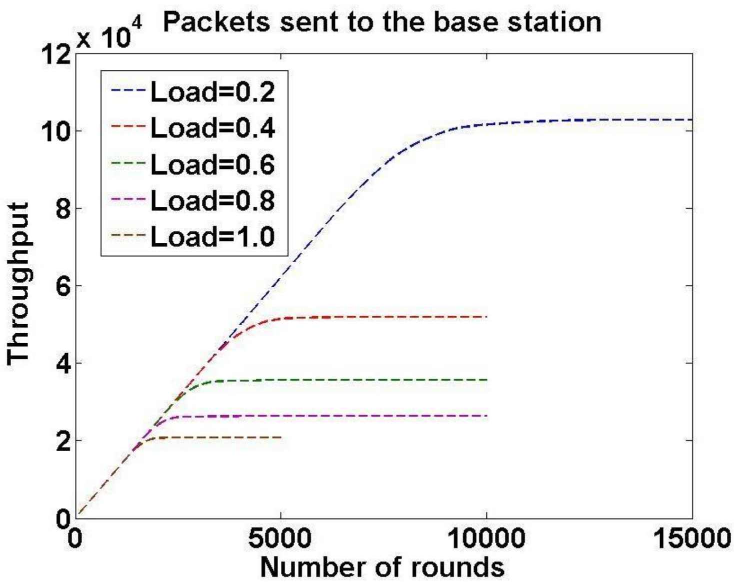

Fig. 5 - Throughput vs. rounds under various loading conditions

In Fig. 5, throughput vs. number of rounds are plotted it is clear from the figure that there is a sharp decline in throughput as the load increases. At the higher loads (≥ 0.8) nodes die earlier thus throughput reduces drastically. At the load of 0.2, the throughput is 1.02×10^5 while at the load of 1.0 throughput is 2.09×10^4. Thus as the load increases to five times, the throughput reduces by a factor of 5.

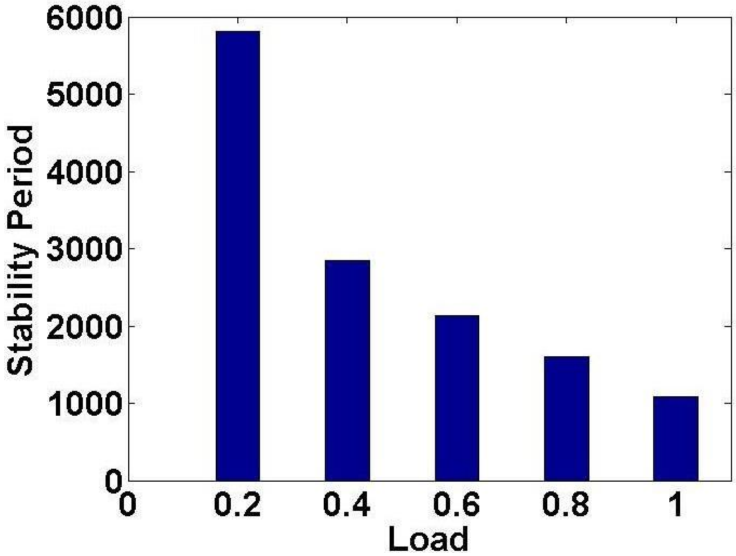

Fig. 6 - Stability period vs. various loading conditions

In Fig. 6, stability period vs. load is plotted. Here load is varied from 0.2 to 1.0 with an increment of 0.2. At the load of '0.2' stability period is 5810 rounds which decreases to 2410 at the load of 0.4 and finally at the load of 1.0 stability period reduces to 1081 rounds. Thus, as the load increases, a sharp decline in stability period is observed. If load is less than 1, then in some of the slots no transmission takes place, therefore battery power remains conserve and stability period increases.

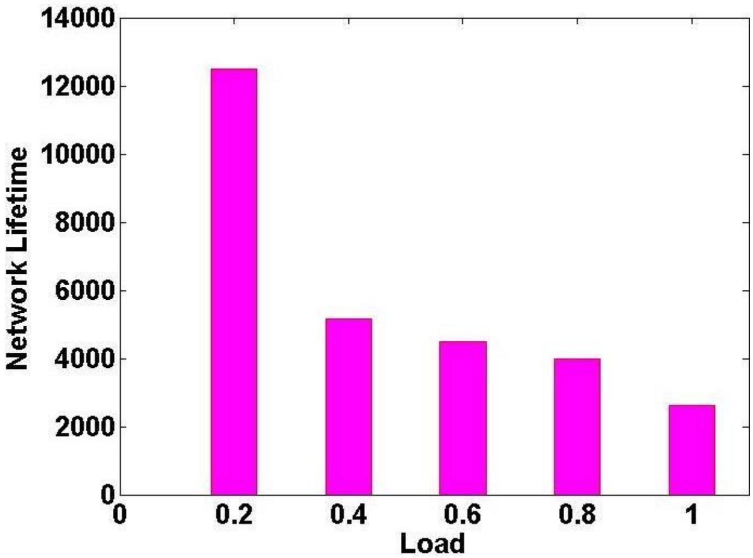

Fig. 7 - Network lifetime vs. various loading conditions

In Fig. 7, network lifetime vs. load is plotted. Here, again load is varied from 0.2 to 1.0 with an increment of 0.2. At the load of '0.2' network lifetime is nearly 12200 rounds which decreases to 5300 rounds at the load of 0.4 and finally at the load of 1.0 network lifetime reduces to 2500 rounds. Thus, as the load increases, a sharp decline in network lifetime is observed. It is also observable that as load crosses 0.4 point, instability period decreases, as number of dead nodes increases significantly. Again if load is less than 1, then in some of the slots no transmission takes place, therefore battery power remains conserve and network life time increases.

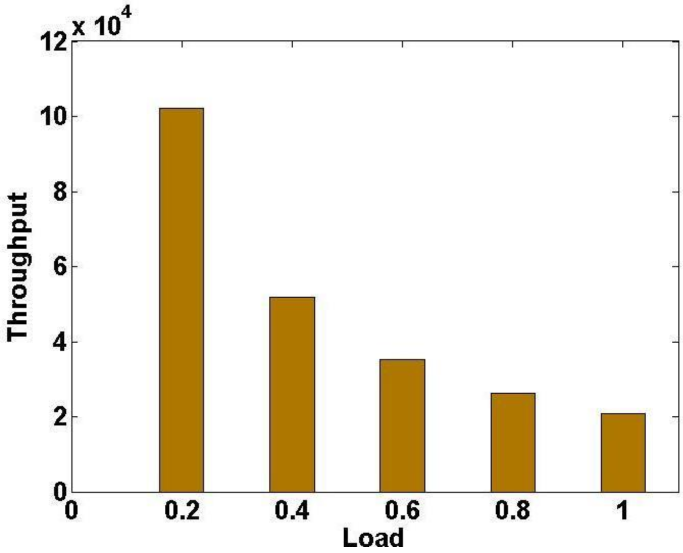

Fig. 8 - Throughput vs. various loading conditions

In Fig. 8, throughput vs. load is plotted. Here, again load is varied from 0.2 to 1.0 with an increment of 0.2. At the load of '0.2' throughput is nearly 1.02×10^5 packets which decreases to 5.19×10^4 packets at the load of 0.4 and finally at the load of 1.0 throughput reduces to 2.09×10^4 packets. Thus, as the load increases, a sharp decline in throughput is observed. It is clear from the figure that an exponential fall is observed with increases in load.

Thus it is clear from the figures that using the concept of the load, network lifetime, stability period and throughput can be varied significantly, and better utilization of battery power is possible. Finally, by reducing load to a very low value, the information transfer can be restricted to once in a week/month or year. Thus, by varying loads from very low value to high value packet transfer can be significantly controlled.

6. Conclusions

In this work a load based packet transfer protocol is proposed, which is useful in application where frequent updates of the information are not desirable. On the basis of obtained results following conclusions can be made:

- The use of network node heterogeneity reduces energy consumptions.
- The loading based transmission, controls the packet transmission to sink.
- At lower loads (≤ 0.4) good stability period, large network lifetime and higher throughput is observed.
- As the load increases stability period, network lifetime and throughput reduces.
- At the load 1 this protocol behaves like a simple protocol, where in each round packets are transferred to sink.
- Thus using different loads packets transfer towards sink can be effectively controlled.

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