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THROUGHPUT ANALYSIS OF POWER CONTROL B-MAC PROTOCOL IN WSN

Ramchand V and D.K. Lobiyal

School of Computer and Systems Sciences,
Jawaharlal Nehru University, New Delhi, India
rchand.jnu@gmail.com
lobiyal@gmail.com

ABSTRACT

This paper presents a new methodology for energy consumption of nodes and throughput analysis has been performed through simulation for B-MAC protocol in Wireless Sensor Networks. The design includes transmission power control and multi-hop transmission of frames through adjusted transmitted power level. Proposed model reduces collision with contention level notification. The proposed model has been simulated using MATLAB. The simulations reveal better results for throughput of the proposed model as compared to B-MAC protocol. In this model we have included a mechanism for node discovery to find the location of the node before transmission of data to it. This increases the throughput of the network since the position of a dislocated node has been found, that results into successful transmission of frames. However, the energy consumption of a node increases due to energy consumed in node discovery.

KEYWORDS

Wireless Sensor Networks, Trigonometry, Possion distribution and Energy efficiency.

1. INTRODUCTION

Wireless communication is the most exciting area in the field of communication research. Over five decades it has been a major topic of research. Wireless Sensor Networks (WSNs) are an emerging technology that has become one of the fastest growing areas in the communication industry. They consist of sensor nodes that use low power consumption which are powered by small replaceable batteries that collect real world data, process it, and transmit the data to their destination nodes or a sink node or a server. WSN based applications usually have comfortable bandwidth requirement, the demand for using this medium is increasing with wide range of deployment for monitoring and surveillance systems as well as for military, Internet and scientific purposes. Wireless sensor networks will play an important role in future generation for multimedia applications such as video surveillance systems.

Transmission power control is provoked from potential benefits. The benefit is a more efficient use of the network resources. Allow a large number of simultaneous transmissions, power control increases the whole network capacity. Secondly energy saving is achieved by minimizing the average transmission power. The transmission power level is directly related to the power consumption of the wireless network interface. The lifetime of node's battery is becoming an important issue to the manufacturers and consumers, as devices are being used more frequently for transmission of signals\data packets\frames. It is becoming great interest to control the transmission power level of every node so that the lifetime of the wireless sensor network will be maximized.

Multiple access-based collision avoidance MAC protocols have made that a sender-receiver pair should first ensure exclusive access to the channel in the sender and receiver neighborhood before initiating a data packet transmission. Acquiring the floor allows the sender-receiver pair to avoid collisions due to hidden and exposed stations in shared channel wireless networks. The protocol mechanism used to achieve such collision avoidance typically involves preceding a data packet transmission with the exchange of a RTS/CTS (request- to-send/clear-to-send) control packet handshake between the sender and receiver. This handshake allows any station that either hears a control packet or senses a busy carrier to avoid a collision by deferring its own transmissions while the ongoing data transmission is in progress.

2. RELATED WORK

MAC layer has a vast impact on the energy consumption of sensor nodes. Communication is a major source of power consumption and the MAC layer design manages the transmission and reception of data over the wireless medium using the radio. The MAC layer is responsible for access to the shared medium. MAC protocols assist nodes in deciding when to access the channel. Pattern-MAC (P-MAC) for sensor networks adaptively determines the sleep-wake up schedules for a node based on its own traffic, and the traffic patterns of its neighbors. This protocol achieves a better throughput at high loads, and conserves more energy at light loads. In P-MAC, the sleep-wake up times of the sensor nodes is adaptively determined. The schedules are decided based on a node's own traffic and that of its neighbors. The improved performance of P-MAC suggests that 'pattern exchange' is a promising framework for improving the energy efficiency of the MAC protocols used in sensor networks [5].

S-MAC protocol achieves energy conserving through three basic techniques [10]. Nodes sleep periodically instead of listening continuously to an idle channel. Transceivers are turned off for the time the shared medium is used for transmission by other nodes overhearing is avoided, and a message passing scheme is used with the help of store-and-forward technique based on the buffer capacity. Each of the nodes has a fixed duty cycle. It can be used to tradeoff bandwidth and latency for energy conserving, but it does not allow adapting to network traffic. However, S-MAC protocol allows transmitting large messages by fragmenting them. It mitigates problems with higher delays and requires large storage buffers.

Power controlled Sensor MAC in wireless sensor network [9] provides a number of benefits. Sharing the medium efficiently therefore, decreasing the overall energy consumption of the network. Furthermore, increases the network capacity and maintains the network connectivity. A power controlled sensor MAC protocol addresses power controlled transmissions in wireless sensor network is an improvement to Sensor MAC protocol. It uses RTS (request to send), CTS (clear to send), DATA, and ACK (acknowledge), called as handshake mechanism. In order to save energy the frames are transmitted with the suitable power level, instead of the maximum power level.

3. PROPOSED METHODOLOGY OF B-MAC

3.1 Analytical model for power consumption

The function of network begins either because of node's mobility or node sensing an event. In order to find the location of dislocated node, "node discovery" will be performed. A node that senses an event, needs to calculate the contention level of nodes in the coverage area, estimate power required for transmission of control packets and frames, and probabilities of control packet and frames to be exchanged.

3.1.1 Discovering Nodes

The term "discovery" is used in many contexts to find the position of an object in physical space with respect to a specific frame of reference that varies across applications. Discovering nodes is the task of identifying two dimension or three dimension positions of the nodes.

Assumptions in discovering nodes:

I. Sensor nodes are deployed statically equidistance to each other in the field to monitor events. Though nodes are mobile, we assume few nodes are stable within one hop communication range through which the location of other nodes can be estimated.

II. Nodes which are placed in the border of the field may go out of transmission or reception range is not given importance to locate their positions.

At the beginning of the network all the mobile nodes are placed at a specific location. All the nodes periodically broadcast a hello message to its neighbor nodes to gather its one-hop neighbor information such as node's location (varies over time) and power availability for communication.

A hello message contains the current list of its one-hop neighbors. Each sensor node has a certain area of coverage for which it can reliably and accurately report the particular quantity that it is observing. Due to mobility the density of network may vary over time. Rapid variation in the density of sensor node leads to frequent changes in the topology.

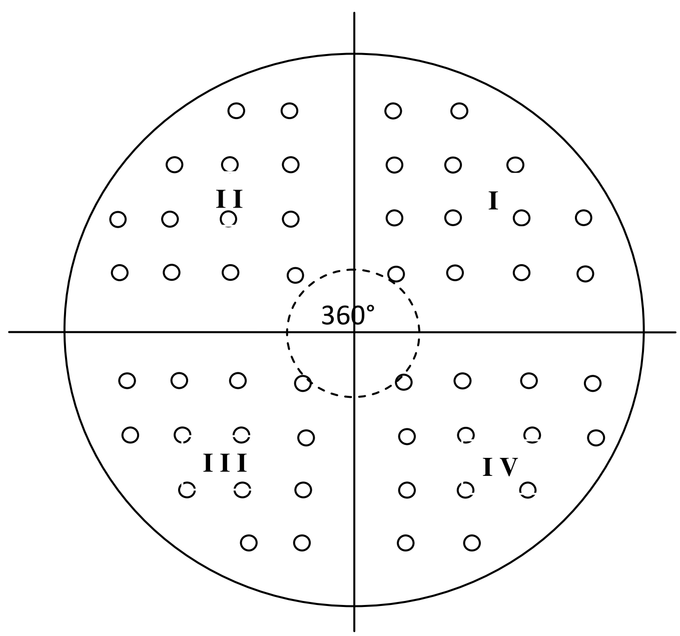

Figure 1. Network Scenario

The above figure is a sensor network were all the nodes are placed in a circular region with the center point of the circular region covering 360° which is divided in to four quadrants. Equal numbers of nodes are deployed equidistance to each other in all the quadrants.

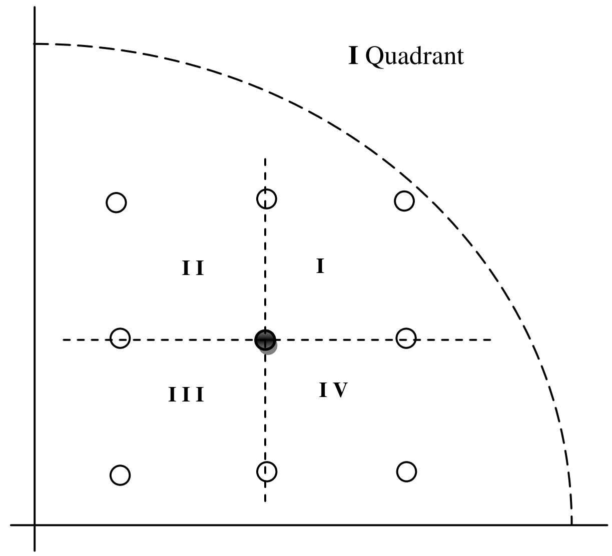

Figure 2. Nodes in I Quadrant

From figure 1 we took first quadrant nodes to find out the mobility of a node at time t with the assumption as stated above. As the network is divided in to four quadrants, every node in the network is surrounded by four quadrants with angles π/2, π, 3π/2 and 0.

3.1.2 Locating angle of nodes

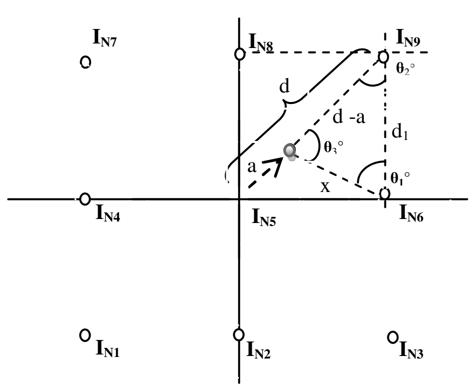

Figure 3a Node in I quadrant

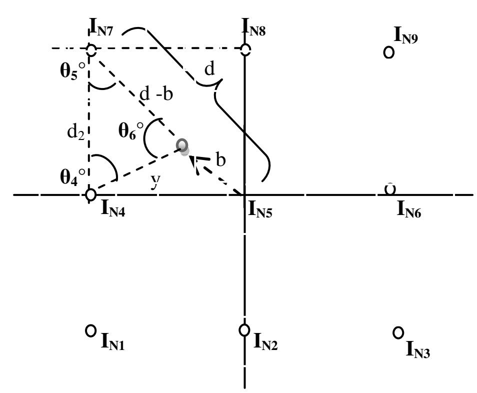

Figure 3b Node in II quadrant

Figure 3a dislocation of a node is the first quadrant, where all the nodes are numbered as I_{N1}, I_{N2},…,I_{N9}. Node I_{N5} has moved towards its first quadrant. The location of node is calculated with the neighboring nodes I_{N6}, I_{N8} and I_{N9}.

$$\angle I_{N9} I_{N6} I_{N5} = 270° - \theta_2°$$

$$\angle I_{N6} I_{N9} I_{N5} = 180° - \theta_1°$$

$$\angle I_{N9} I_{N5} I_{N6} = ((270° - \theta_2°) + (180° - \theta_1°)) - 180° = \theta_3° \quad (1)$$

d_1 is the distance between nodes I_{N6} and I_{N9}. Node I_{N5} has moved a distance from its original location. d-a is the distance between nodes I_{N5} and I_{N9}. x is the distance between nodes I_{N5} and I_{N6}.

In figure 3b the same node I_{N5} has moved towards its second quadrant its new location is calculated with nodes I_{N4}, I_{N7} and I_{N8}.

$$\angle I_{N5} I_{N4} I_{N7} = 180° - \theta_4°$$

$$\angle I_{N5} I_{N7} I_{N4} = 270° - \theta_5°$$

$$\angle I_{N7} I_{N5} I_{N4} = ((270° - \theta_5°) + (180° - \theta_4°)) - 180° = \theta_6° \quad (2)$$

d_2 is the distance between nodes I_{N4} and I_{N7}. Node I_{N5} has moved b distance from its original location. d-b is the distance between nodes I_{N5} and I_{N7}. y is the distance between nodes I_{N5} and I_{N4}. Similarly same node may move to any quadrants and can be identified with trigonometry.

3.2 Transmission power control

The network function begins when a node senses an event and starts transmitting the sensed event in the form of message, data, frame or packet etc. The task of a node is to sense for events, transmit \ receive the data with other nodes, forward the data to a head node or sink node when ever required until the battery power drains. On a given time, either a node or few nodes may transmit out of N number of nodes deployed in the field.

Therefore, the probability of a node involved in transmission is $p_{n=1}(t) = 1/N$. Similarly the probability of more than one node involved in transmission is $p_{n=2,..,N-1}(t) = N - 1/N$

The probability of transmitting nodes varies over time. Nodes active time, sleep time idle time as followed as per analytical model for power control T-MAC protocol [3]. At the initial stage of the network all the nodes are equipped with equal energy. Therefore, more number of nodes may employ themselves in sensing the events. Those nodes which have sensed some events will involved in forwarding of events as frames or signal, it leads to increase in high contention level among neighboring nodes. Any node before initiating a transmission estimates contention level to avoid collision with others.

$$C_L = A_N - \sum_{i=1}^{n} \pi r^2 * \frac{n_t}{N_A} \quad (3)$$

C_L is the contention level

A_N is any node that measures the current contention level among neighbors.

$\sum_{i=1 \text{ to } n}$ are the nodes which are in contention to communicate.

πr^2 is the circular area where all the contending nodes reside.

n_t is the number of nodes contending at time t and

N_A is total number of nodes in a given area.

A node that wins the contention starts transmitting. Once the transmission is over the node goes to listen state. Further, nodes which are in the backoff mode wake up once the timers expire.

3.2.1 Contention Notification

Contention Notification (CN) messages alert the neighbor nodes not to act as hidden terminals when contention is high. Every node makes a local decision to send a CN message based on its local estimates of the contention level. Estimating contention level is either by receiving acknowledgment from the one-hop receiver or by measuring the carrier to noise plus interference ratio between the source and destination. Other way of estimating contention is by measuring the noise level of the channel. Any node in the network that has a frame to transmit senses the channel with the Clear Channel Assessment algorithm before initiating the transmission. When the noise level of the channel is higher than CCA threshold, the node takes random backoff. A node starts transmitting only when the noise level of the channel is smaller than CCA threshold. Noise level of a channel is measured by carrier to noise density ratio (CNDR),

$$CNDR = \left(E_f / n\right) * \left(N / C_A\right) * \frac{R}{B} \tag{4}$$

where E_f is the energy consumption in one frame transmission,
n is the noise level of current frame transmission,
N/C_A is number of nodes in given coverage area
R is the rate at which a frame is transmitted and
B is the channel bandwidth.

3.2.2 Power estimation of nodes

Source node transmit a frame to a destination node,

$$P_r = P_t \left(\frac{\lambda}{4\pi d} \right)^n \tag{5}$$

Given P_t is the transmit power of source and P_r is the power when the frame reaches the receiver. λ is the average arrival rate, and d is the distance from source to destination. n is the noise level of the channel. Source node sends RTS to destination node with the power level P_t, and the destination node receives the RTS package with the power level P_r then,

$$P_r = P_{frame} \left(\frac{\lambda}{4\pi d} \right)^n$$

$$\text{where} \quad P_{frame} = \frac{P_t R_s}{P_r}$$

where R_s is the sensitivity of received signal, sensitivity in a receiver is normally defined as signal s produce noise ratio at the transceiver / receiver node.

$$S_i = k\left(N_s + N_r\right) B * SNR$$

S_i is the Sensitivity
K is the Boltzman constant

N_s equivalent noise at source node
N_r equivalent noise at receiver node
B is bandwidth
SNR signal to noise ratio

Communication between source node to destination node with power level P_{frame} and the signal-to-noise radio (SNR) is not less than threshold Th, that utter the need for a minimal received power level,

$$\frac{P_{frame}}{N_{pr}} \geq Th$$

where N_{pr} is the noise power at receiver.

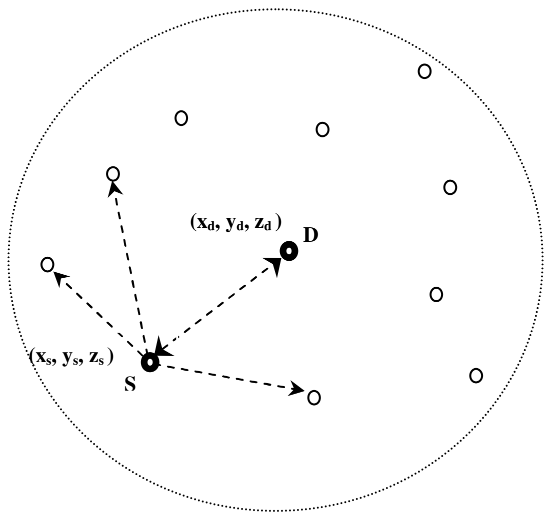

Figure 4. Dislocated nodes of WSN

Consider a source node at the location vector S = (x_s, y_s, z_s). The destination is located within the range of N+1 receiver at the location D = (x_d, y_d, z_d). The distance d from the source to one of the receivers in terms of the coordinates is

$$d_{sd} = \left|\vec{D} - \vec{S}\right| = \sqrt{(x_D - x_S)^2 + (y_D - y_S)^2 + (z_D - z_S)^2}$$

$$d_{sd} = \sqrt{(x_{D-S})^2 + (y_{D-S})^2 + (z_{D-S})^2} \qquad (6)$$

Strength of the received frame is calculated with the use of log normal model of radio signal propagation between the source and destination nodes.

$$ss_D = TP_S - p_L - 10_n \log(d_{sd}) \qquad (7)$$

ss_D is the received signal strength of the destination node.
TP_S is the transmitted power of source node.
P_L is Path loss, n is the path loss exponent.
d_{sd} is the distance between source and destination node, calculated from equation (6).

3.2.3 Adjusted transmission power

Let P_{max} is the max transmission power of nodes, and P is the current transmission power of node. E_{max} is the maximum energy level of nodes at the initial stage of the network operation begins, with *Pres* is the residual power of a node. Optimal degree of a node is N, current degree of node is n.

To adjust the transmission power according to suitable degree, the adjusted transmission power P_{adj} is shown below,

$$P_{adj} = P + \left[\frac{N-n}{N}\right] * P$$

Further transmission power of node will be based on its residual power. Therefore, power available P_{AVAIL}

$$P_{AVAIL} = \left(\frac{P_{res}}{E_{\max}}\right) * P_{\max}$$

According to the residual power, improved adjusted power IP_{adj} is given as,

$$IP_{adj} = P_{adj} + \left[\left(\frac{P_{res}}{E_{\max}}\right) * P_{\max}\right] - P \tag{8}$$

3.2.4 Probabilities of control packets and frame exchange

When a node acquires frames for transmission at the rate λ_r and arrival follows Poisson distribution. On a frame to transmit it initiates the transmission with control packet exchange. To transmit an RTS packet a node takes μ_R time, therefore the average arrival rate of receiving an RTS packet $\lambda = \frac{1}{\mu_R}$. Therefore, probability of transmitting an RTS packet is calculated as

$$P(X=1) = \frac{e^{-(1/\mu_R)} * (1/\mu_R)^1}{1!} \tag{9}$$

On arrival of RTS packet the receiver calculate the power level of the transmitted control packet and reply the CTS packet with required power level. The probability of replying the CTS packet is represented as

$$P(X=1) = \frac{e^{-(1/\mu_C)} * (1/\mu_C)^1}{1!} \tag{10}$$

The node on receiving the reply it forwards the acquired frames to its one hop neighbor node. The frames are forwarded at the rate λ_r. Therefore, the power consumption of transmitting node is

$$P_t = p_r\lambda_r + \frac{e^{-(1/f)} * (1/f)^1}{1!} \tag{11}$$

where $\left(e^{-(1/f)} * (1/f)^1\right)/1!$ is the probability of receiving a frame and p_r is the power consumed for receiving a frame.

On arrival of frame the receiver calculates the power level of the transmitted frame, it reply the ACK with required power level. The probability of replying the ACK is represented as

$$P(X=1)=\frac{e^{-(1/\mu_{ACK})}*(1/\mu_{ACK})^{1}}{1!} \quad (12)$$

On arrival of ACK from the receiver the transmitting node sends the remaining frames with adjusted transmit power. Power consumption of a node transmitting frames with the adjusted power is given by

$$P_{t(IP_{adj})}=p_{r}\lambda_{r}+\frac{e^{-(1/f)}*(1/f)^{n}}{n!} \quad (13)$$

where $\left(e^{-(1/f)}*(1/f)^{n}\right)/n!$ is the probability of receiving *n* number of frames

4. SIMULATION RESULTS

The proposed model for estimating energy consumption in B-MAC protocol is implemented in mat lab. Proposed methodology has been designed with fewer numbers of mobiles nodes which are placed equidistance to each other. All the nodes are mobile by nature they relocated their positions subject to requirements of the tasks of their own or with the request of nodes with one hop communication range. The proposed protocol has been tested for unicast and broadcast communication with multi-hop transmission of frames. For unicast communication control packets like RTS-CTS are used. Adjusted transmission power level is used for broadcast communication. After broadcasting a frame, all nodes in the coverage area should refrain themselves from transmitting until one frame time has elapsed to allow transmitting the other node initiating a transmission is more efficient than control packet exchange for broadcast traffic. Frame length is varied as per the requirement of the application. The Simulation parameters used in the work are listed in the tables below

Table 1a Simulation parameter

Parameter	Value
Number of nodes	20
Contention window per slot duration	400 µs
Communication bandwidth	15 Kbps
Transmission Range	2 meters
Transmitting and Receiving antenna gain	Gt=1, Gr=1
Transmission power	0.031622777W
Carrier Sense Power	5.011872e- 12W
Received Power Threshold	5.82587e-09W
Traffic type	VBR
Initial Energy	500 Joule

Table 1b Frame parameters

Length (Bytes)	
Preamble	8
Synchronization	2
Header	5
Footer (CRC)	2
Frame length	Variable

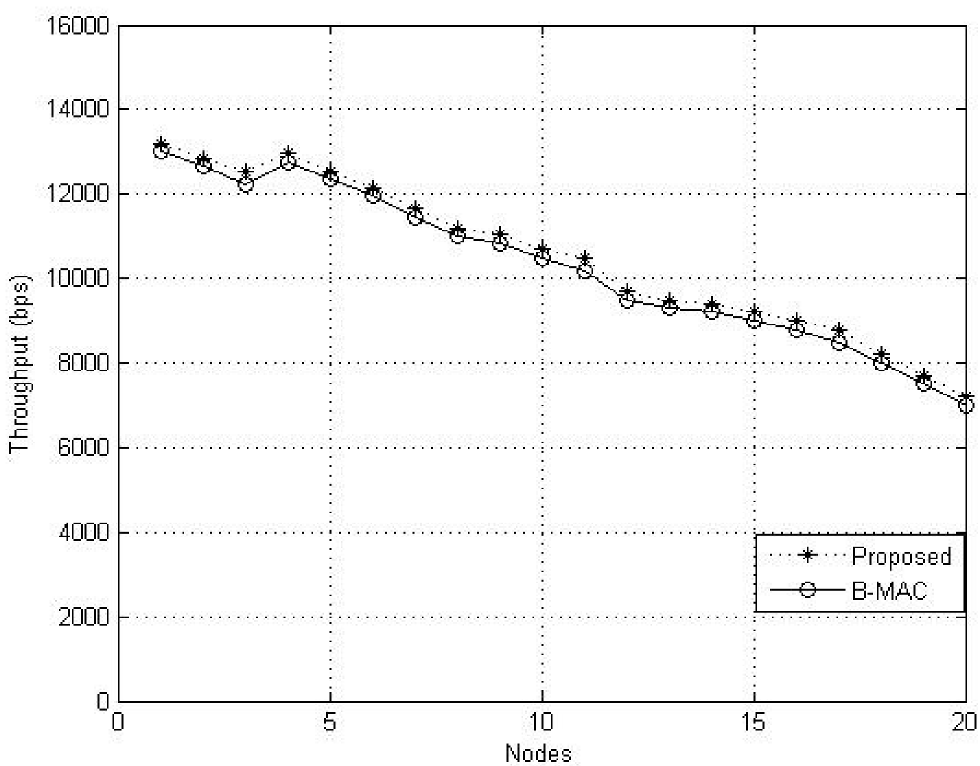

Figure 5 Throughput

The above figure shows the throughput of existing B-MAC protocol and the proposed model. Under low transmission rate unicast messages are exchanged with the use of control packet transmissions. Adjusted transmission power level is used for broadcasting frames. Proposed model deliver frames and achieves marginally better throughput for multi-hop transmission of frames than the existing work.

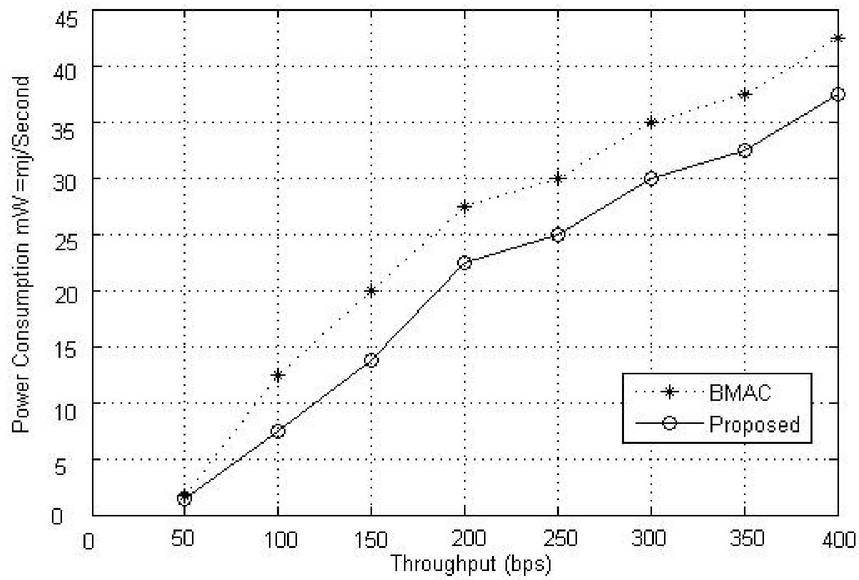

Figure 6 Power consumption

The above figure shows the comparison of energy consumption between B-MAC and proposed model. Energy efficiency is measured based on unicast, broadcast and multi-hop transmission of frames. While measuring the efficiency, sending rates are varied. The above figure presents the energy consumption of nodes involved in different duty cycles. As we observe in the multi-hop throughput, under low data rates, existing MAC has slightly lower throughput. The figure also shows the impact of the bits transmitted per second and power consumption of nodes in milli-watts. It is quite clear from the figure that the proposed work out performs the existing MAC in energy consumption.

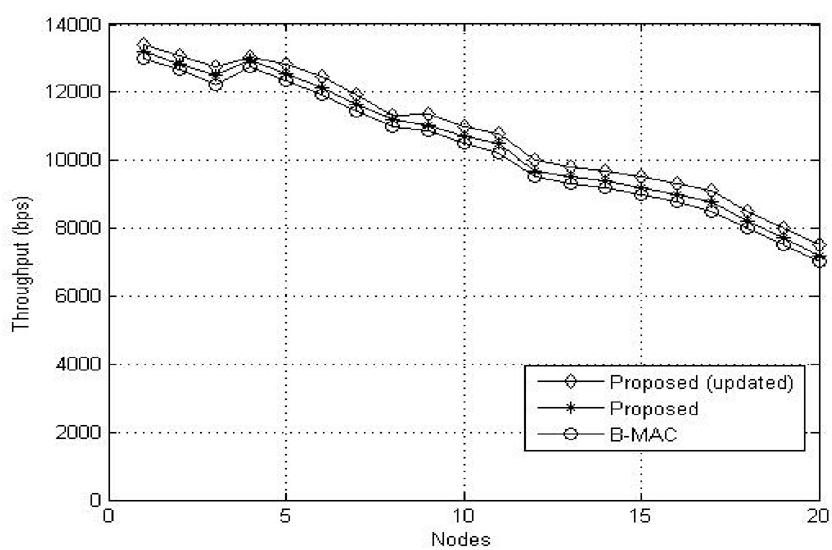

Figure **7** Improved Throughput

The above figure shows the throughput of existing B-MAC protocol, proposed model and proposed model with discovery of nodes. Proposed model deliver frames and achieves slightly better throughput than the existing work. Node discovery increases the overall throughput of the network.

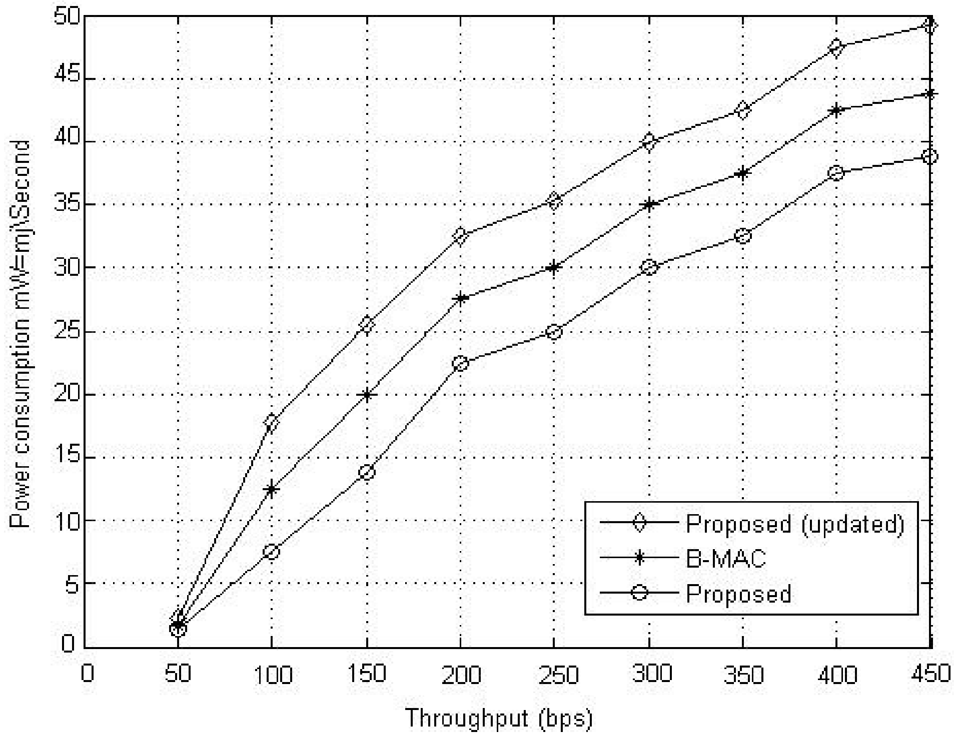

Figure 8 Power Consumption (depletion)

The above figure shows the comparison of energy consumption between B-MAC protocol, proposed model and the proposed model with node discovery. While discovering the dislocated nodes consume more energy. The figure shows the impact of energy depletion as compared with B-MAC protocol, power consumption of nodes is indicated in milli-watts.

5. CONCLUSION

In this work, we have proposed analytical model for estimating throughput of multi-hops and energy consumption in B-MAC protocol for Wireless Sensor Networks. The power consumption for an individual node is calculated for multi-hop communication. A node in the network saves its energy by changing its mode periodically. The proposed protocol shows better results than B-MAC protocol in terms of energy consumption. While designing the methodology for B-MAC, utilization variation in synchronization errors and transmission fairness and border nodes going away from the transmission are not focused, also when focusing on node discovery we obtaining better throughput but at the cost of power depletion of nodes. This may be explored in the future work.

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Authors

Mr. Ramchand V. received his M.Sc. (Computer Science) and M.Tech (Computer Science and Engineering) from Bishop Heber College, Tamilnadu, India. and S.R.M University, Tamilnadu, India in 2005 and 2007 respectively. Currently Mr. Ramchand is pursuing Ph.D (Computer Science) in the area of Transmission power control in Wireless Sensor Networks in the School of Computer & Systems Sciences, Jawaharlal Nehru University, New Delhi, India.

Dr. D.K. Lobiyal received his Ph.D and M. Tech (Computer Science) from School of Computer and Systems Sciences, Jawaharlal Nehru University, New Delhi, India in 1996 and 1991, respectively, and B. Tech. (Computer Science and Engineering) from Lucknow University, India in 1988. He is currently working as Associate Professor in the School of Computer and Systems Sciences, Jawaharlal Nehru University, New Delhi, India.
His research interest includes Mobile Ad hoc Networks, VoD, Bioinformatics and Natural Language Processing. He has published papers in International Journals and Conferences including IEEE, Wiley & Sons, Springer, Inder Science, WSEAS, IGI Global, and ACTA Press.