# Review of Transmission Power Control Techniques in MANET

Suchismita Rout, Ashok Kumar Turuk, and Bibhudatta Sahoo

***Abstract***— Now-a-days more and more devices are getting portable. In addition to device portability, MANET does not require a pre-established network infrastructure. As a result they can be deployed in situations like emergency rescue and disaster management. Nodes in MANET are run by battery power. Sometimes, it is difficult to replace and/or re-charge battery. Therefore, to increase the longevity of the network, the available battery power must be judiciously used. There have been various research activities in this area to increase the network lifetime. Different energy conservation techniques have been proposed by various authors. This paper surveys and classifies various energy aware routing protocols proposed in MANET. We present taxonomy of energy efficient routing protocol, their properties and design features. This paper aims to provide platform for those MANETs researchers in selecting appropriate routing protocol.

***Keywords—***Transmission Power, Reception Power, Topology Control, Duty cycling.

## I. Introduction

MANET is infrastructure less collection of mobile nodes with multi hop network gives fast network establishment, that communicate over relatively bandwidth constrained wireless links [1] [2]. Each node operates on limited battery energy. Power management becomes more challenging problem in mobile ad hoc network. Many research activities are devoted in this area to stronger the network life and reduce the energy consumption in network. Power consuming is the most energy consuming activities in MANET, so this limited battery energy must be controlled in an efficient manner during transmission and reception process. The adjustment of transmission power through the dynamic transmission power control protocol is an effective technique to reduce the power consumption of a network [3] [4]. To carefully manage this scarce energy resource different energy efficient techniques have been used [5]. Transmission power control is one of the techniques to conserve energy in MANET by changing the transmission power of a node. As more transmission power leads to high energy consumption and vice versa. In the IEEE 802.15.4 MAC protocol, each node transmits packets at the same power level which is its maximum transmission power. But, if a node uses high power for its transmission then it may generate too much interference and consume more energy than necessary. In dense network when two nodes are close to each other, a low transmission power is sufficient for communication [6]. The power level should be high enough to guarantee the transmission and should be low enough to save energy in mobile environment [7]. Optimization of transmission power is a means to improve lifetime of wireless network and reduce the interference beginning in literature [8] [9].

Transmission power defines an arrival range of packet and directly link to the energy consumption of a network. In excess wide arrival range of packets in a dense network causes many problems like packet collision, interference which degrading the performance of network [10] [11] [12]. The excessive transmission power degrades the network performance with problem like overhearing. Adjustment of transmission power is divided into two categories: adjust transmission power so that all nodes take a single transmission power and adjust transmission power specifically per node or per link unit. Transmission power adjustment is again divided into two parts: node adjust transmission power depending on the distance between nodes or depending on radio frequencies. It conserves energy of a network and improves network performance [13] [14] [15].

Rest of paper is organized as follows. Section 2 gives an idea regarding energy consumption in MANET. Section 3 illustrates energy consumption techniques in MANET. Overview of problem in channel environment is given in section 4. Section 5 discusses related work. Finally it concludes with conclusions in section 6.

## II. Energy Consumption in MANET

In the entire process of communication and computation, mobile node exists in four modes as given in equation 2. As per the communication takes place the node undergoes transition from one state to another. From Equation 3 it is observed that the mobile node consume least power in sleep state as compared to other state. Since the battery resource is limited so it is advised to put the node in sleep state when it is not in use.

$$E_{total} = E_{path-discovery} + E_{packet-transmission}$$
$$E_{path-discovery} \alpha control - packets \qquad (1)$$

$$E_{packet-transmission} = E_{idle} + E_{active} + E_{sleep} + E_{overhear} \qquad (2)$$

$$E_{active} = E_{recv} + E_{transmit} \qquad (3)$$

$$E_{sleep} \cong 0 \qquad (4)$$

The amount of energy consumption in various modes is given in following subsection [16].

### A. Power consumption in Transmission mode:

In transmission mode node sends data packet to other node in a network. The energy required to transmit the data packet is called as Transmission Energy, it depends on size of data packet (in Bits). The transmission energy is formulated as:

$$E_{transmit} = (330 * P_{length}) / 2 * 10^6$$

$$P_T = E_{transmit} / T_t$$

Where $E_{transmit}$ is the transmission energy, $P_T$ is Transmission Power, $T_t$ is time taken to transmit data packet and $p_{length}$ is length of data packet in Bits.

### B. Power consumption in Reception mode:

In reception mode a node receives the data packet from other node and the energy required to receive data packet is called Reception Energy. The reception energy is given as:

$$E_{recv} = (230 * P_{length}) / 2 * 10^6$$

$$P_R = E_{recv} / T_r$$

Where $E_{recv}$ is the reception energy, $P_R$ is Reception Power, $T_r$ is time taken to receive data packet and $p_{length}$ is length of data packet in Bits.

### C. Power consumption in Idle mode:

In this mode, a node is neither transmitting nor receiving, but it consumes power unnecessarily by listening to the wireless medium continuously till it consumes a considerable amount of energy. Detect whether a packet it should receive, so that it can switch into receive mode from idle mode. In idle mode a node does not involve in any data communication process, still it consumes a considerable amount of energy. This energy is same as the amount of energy consumed in reception mode. The power consumed in idle mode is:

$$P_I = P_R$$

Where $P_I$ is power consumed in idle mode and $P_R$ is power consumed in reception mode.

### D. Power consumption in Overhearing mode:

In overhearing mode, a node listens to the packet that is not destined for it. The energy consumed in this mode is same as reception mode. Unnecessarily it consumes energy in receiving the packets. The Power consumed in overhearing mode is:

$$P_{Over} = P_R$$

Where $P_{Over}$ is power consumed in overhearing mode and $P_R$ is power consumed in reception mode.

To maximize network lifetime various power conservation techniques have been proposed to improve energy efficiency. A few of such schemes are described briefly in the next section.

## III. ENERGY CONSERVATION TECHNIQUES

Some significant work has been done to achieve energy efficiency in MANET. Different techniques are proposed in literature to improve energy efficiency. Power conservation technique can be broadly classified into two types:

- Topology Control Approach
- Transmission Power Management Approach

### A. Topology Control Approach

Due to mobile manner of wireless nodes, the construction of MANET called topology changes dynamically [17]. Topology of MANET is affected by many uncontrollable factors like node mobility, weather conditions, environmental interference and obstacles and some controllable factors like transmission power, antenna direction and duty-cycle scheduling. The topology control is an effective technique for power saving. The topology of MANET is considered as graph with its nodes as vertices and communication links between node pairs as edges. The edge set is large possible one as normally the communication is established by node's maximum transmission power. In dense network too many links leads to high energy consumption, network throughput, and quality of services. The primary target of topology control is to replace long distance communication with small energy efficient hops. The dense network while ensures tight connectivity at the same time causes interference where in sparse network every node needs to be part in data communication as connectivity is being a question. So there is a tradeoff between network connectivity and sparseness [18]. For two nodes u and v the energy consumption of their communication grows quadratic ally with their distance.

The topology control problem can be defined as follows: let V denotes the set of wireless nodes and E representing the set of communication links in the graph G = (V, E), before running topology algorithm. If all nodes use maximum transmit power $P_{max}$ then the edge (u, v) between node u and v, exists in the edge set E if node u and v can directly communicate with each other. Running topology control algorithm will yield sub graph G' = (V, E') of G. In G' nodes have shorter edges and fewer degrees than that in G and following the property of connectivity (two nodes u and v are connected if there is a path between u and v, better if through multi hops) and symmetry (if node u is a neighbor of v if and only if v is a neighbor of node u).

In MANET the rate of change in routing topology with transmission power can optimize performance metric such as network life time and throughput. By controlling network topology network throughput is enhanced because of two benefits. First the interference is reduced by varying transmission radii of nodes to near one, second more data transmission is carried out simultaneously in the neighborhood of a node. If a network has bad topology, there may be adverse effect such as low capacity, high end-to-end delay and weak robustness to node failure [19].

### B. Transmission Power Management Approach

Power management approach basically decides when to switch off radio transceiver of the mobile terminal to save energy. This power management state can also be called as sleep/power down mode [20]. Turning the transceiver off make the node not to listen to the cannel and not take in active participation in packet transferring. So turning off the station should be done with a condition not to incorporate delays in packet transmission. The synchronization should be maintained in routing so that switching off one node does not affect the performances of overall network connectivity. For selecting the node to put in sleep state the master node is selected as in SPAN and GAF protocol. Some time the network is divided virtual cluster and cluster head at each cluster control the overall network operation.

A routing algorithm in MANET finds the optimal route in between source destination pair for successful communication [21]. If the two nodes are coming in each other transmission range then the direct communication is possible, otherwise the communication is carried out by the intermediate nodes acts as routers. When the transmission range is controllable, their direct communication range as well as the number of its immediate neighbors is also adjustable for giving reliable communication. The stronger transmission range reduces the number of hops, whereas weaker transmission power makes the topology sparse resulting in network partitioning and high end-to-end delay due to large hop count [22]. The power of transmission range is directly proportional to node's battery energy. Increasing the transmission power make more energy consumption and vice versa. Also transmission power affects the interference and collision which may lead to retransmission causing unnecessary energy consumption. Power control is to utilize node's transmission power to reduce interference and to save energy. For energy efficient routing an appropriate transmission power of data packets at each node is decided [23]. The fixed transmit power approach may not be feasible as it won't give guaranty of finding neighbor within a node's fixed transmission power. So in some cases the maximum transmission power is used for control message and minimum required power for subsequent data reception.

## IV. PROBLEM OF CHANNEL ENVIRONMENT

For 802.11 standards, power control techniques have been classified into 3 categories: (i) contention based schemes, (ii) interference based scheme, and (iii) scheduling based schemes [24]. In contention based schemes, RTS and CTS packets are sent at highest power level, DATA and ACK are sent at minimum power level that is necessary to communicate with each other. Though this scheme helps in energy consumption but also it reduces network throughput as DATA and ACK packets are collided with each other causing retransmission of packets. In interference based schemes the node compute the maximum allowable power level that will not corrupt communication among the nodes. This is done by exchanging collision avoidance information in control packet. This incurs more overhead with control packet, though it increases the throughput. In scheduling based schemes the scheduling in frequency (FDMA), time (TDMA) and code domain (CDMA) is used to coordinate the transmission between the nodes by avoiding the collision. In this method each user is assigned with the predetermined and fixed portion of wireless physical resource for eliminating the interference among different users. This allocation method is not efficient and is not flexible with dynamically changing demand [25].

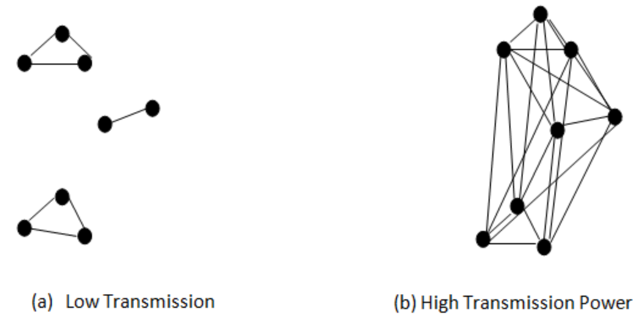


Figure 1: Effect of Power level on Network

The transmission power determines the range over which the signal can be received to determine the performance of network such as throughput, delay and energy consumption. It has been shown that for a better network capacity packet must be transmitted to the nearest neighbor in forward direction. The intuition is if transmission increases the number of hops by two but decreases the area of reserved floor by one fourth of its original value. It allows the concurrent transmission in the neighborhood.

In other hand for increasing network throughput, reducing the transmission power is an important factor for reducing the energy consumption. The battery power of a mobile node is directly proportional to the transmitted signal. So to increase the node lifetime, the signal transmission power must be utilized effectively. So to increase the throughput of a network the transmitted signal power of a mobile node is reduced and at the same time the packet is transferred in multi hop fashion. Further by reducing the transmission range, some active links are reduced, potentially partitioning the network. So to maintain the connectivity the transmission range must be selected not to impact on connectivity.

In the wireless channel energy fading amplifies as distance increases. In realistic environment two ray ground propagation model is used to describe the fading property. The power of reception signal is described as [24]:

$$P_r(d) = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4} \tag{1}$$

In (1), $P_t$ is the transmission power, $P_r$ is the reception power, $G_t$ is the gain of transmission antenna, $G_r$ is the gain of reception antenna, d is the distance between the sender and receiver, $h_t$ is the height of transmission antenna, and $h_r$ is the height of reception antenna.

The magnitude of a reception signal will vary randomly based on the $P_r$ from Two Ray Ground model in very short time or distance. Suppose there are L rays altogether, $a_k$ and $\Phi_k$ be the amplitude and phrase of the k-th ray respectively, so the strength of the total reception signal is:

$$S_R(t) = \sum_{k=1}^{L} a_k \cos[w(t-t_0)+\phi_k]$$
$$= x\cos w(t-t_0) - y\sin w(t-t_0)$$
$$and \begin{cases} x = \sum_{k=1}^{L} a_k \cos\phi_k \\ y = \sum_{k=1}^{L} a_k \sin\phi_k \end{cases} \quad (2)$$

By the central theorem of probability, if value of L increases the random variable x and y become Gaussian distributed as $\cos\phi_k$ and $\sin\phi_k$ becomes orthogonal. The value of x and y are correlated and independent. The reception signal $S_R(t)$ is random variable shown as.

Then $a = \sqrt{x^2 + y^2}$

Because the reception power is proportional to the envelope of signal a random factor which is valued from 0 to 1 and is proportional to α, that is $\alpha^1 \in (0,1), \alpha^1 \ell a$, the reception power is expressed as $\alpha^1.P_r$.

In Equation 1, if the reception signal is proportional to the envelope of signal that vary from 0 to 1. The transmitted signal $P_t$ is vary with the distance. The transmitted signal $P_t$ may vary very much. If fixed transmission power is used the network cannot adapt to the change in distance. If $P_t$ is fixed in case of small communication distance the energy is wasted unnecessarily in transmission power. In case of the distance is very high the transmission power is insufficient to send the packet to next hop. Many research activities are progressed in this area for controlling the transmission power of a node depending upon the distance.

## V. RELATED WORK

### A. PARO Model

PARO is a Power aware routing optimization that helps to minimize the transmission power to forward the packets from source to destination [26]. In network all the nodes are located within the maximum transmission range of each other. In packet forwarding technique one or more nodes elect to be redirectors on behalf of source destination pairs to forward the packets with reduce transmission power. In this way they decrease the overall transmission power to deliver packets in network, by increasing the operational lifetime of network. PARO is applicable in number of networking environments as sensor network, home network and mobile ad hoc networks. It assumes that each radio is dynamically adjusting its transmission power on per packet basis. Instead of broadcast based approach it supports node-to-node based approach for selecting the route. It is based on the assumption that the transmission power required to transmit packet from node A to node B is same as from node B to node A with the condition that interference/fading in both the direction is same. PARO accommodates both in static and mobile environments.

### B. DELAR Protocol

It is a cross-layer designed Device-Energy-Load-Aware relaying framework, named DELAR to achieve energy conservation [27]. It achieves energy conservation from multiple facts including power-aware routing, transmission scheduling and power control. It is a power aware routing protocol that incorporates device heterogeneity, residual energy in information of node and load to save energy.

It consists of heterogeneous ad hoc networks, where most nodes, denoted by B-nodes, equipped with limited power sources like battery, while other nodes called P-nodes with unlimited power.

DELAR is a hybrid transmission scheduling scheme which is a combination of reservation based and contention based medium access control schemes, to co-ordinate transmissions. It is a cross layer design as it introduce mini-routing into data-link layer and Asymmetric MAC (A-MAC) scheme to support MAC layer acknowledgements over unidirectional links caused by asymmetric transmission power level between P-nodes and B-nodes. Multipacket transmission is used to improve the end-to-end delay performance.

### C. OMM Protocol

O*nline Max-Min Routing* protocol optimizes two metrics of the nodes in network: minimizing power consumption (min-power) and maximizes the minimal residual battery power (max-min) [28]. With the help of second metric overloaded nodes can be avoided. Given all link costs, the protocol first finds the optimal path using the Dijkastra's algorithm (single source shortest path algorithm). This path consumes minimum power ($P_{min}$) but it is not the desired max-min path. To optimize the second metric a list of optimal paths are selected without much deviating from optimal value (i.e, $zP_{min}$), it selects the best path that optimizes the max-min metric.

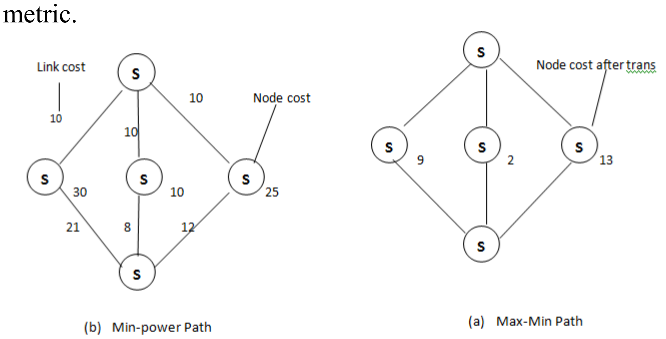


Figure 2: Min-power path and max-min path in the OMM protocol

In Figure 2 it shows an example of the algorithm for a given source (S) and a destination (D) pair. In Figure 2(a), S→B→D is the min-power path as it consumes the minimal energy ($P_{min}$ =18). If z=2, alternative paths S→A→D (path cost=22) and S→C→D (path cost=31) can also be considered since their path costs are within the tolerance range ($zP_{min}$ =36). In order to obtain the max-min path among those three path candidates, the node with the minimal residual power in each path must be compared. In this example, each path contains only one intermediate node and thus their residual energies (nodes A, B, and C) are compared. Node C has the residual energy of 30 but it will drop to 9 if that path is used to transfer the packets from S to D. Similarly, nodes A and B will have the residual energy of 13 and 2, respectively, a shown in Figure 2(b). Therefore, the max-min path among the three min-power paths is S→A→D. The parameter z measures the tradeoff between the max-min path and the min-power path. When z=1, there will not be any alternative path candidate other than the optimal min-power path.

### *D. PLR Protocol*

The Power Aware Localized Routing protocol assumes that the source node has the location information about all the nodes and destination [29]. It can find the link cost between its neighbors and destination. The source cannot find the optimal path but it selects next hop to transfer packet. The source node finds the link cost to its neighbor nodes. The node for which the link cost is minimum that node is selected as next hop. The same procedure is repeated for the intermediate nodes till the destination node is reached.

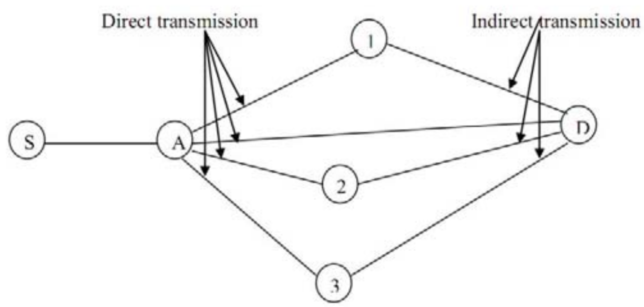


Figure 3: Selection of the next hop node in the PLR protocol.

In Figure 3, to send the data packets from node A to node D, A can either send them directly to D or via one of its neighbors i=(1, 2, or 3). From node A to i is a direct transmission while i to D is an indirect transmission with some number of intermediate nodes between i and D. For selection of the optimal route, node A evaluates and compares the power consumption of each distance is known, i.e., $p(d)=ad^a +c$, where a and c are constants, d is the distance between two nodes. The power consumption of indirect transmission is minimized when (n-1) equally spaced intermediate nodes relay transmissions along the two end nodes, and the resultant minimum power consumption is $q(d)^2$. So each node A, whether it is a source or an intermediate node, selects one of its neighbors (1, 2, or 3) as the next hop node which minimizes p(|Ai|) + q(|iD|).

### *E. TPC-BS Protocol:*

Transmission power defines arrival range of packet and directly proportional to the battery source. High transmission range of packet in a network with densely populated nodes causes problem like packet collision and overhearing and negatively influence on network. TPS-BS algorithm is based on the selection of transmission power of a node depending upon the distance between the nodes [30]. This paper finds an optimal transmission power range dynamically using binary search scheme and minimize overhead in finding the same using multiple message transmission. This value of transmission power is used for transmitting data packets. This determined transmission power can be modified dynamically with changing network environment.

This algorithm determines the transmission power in two phases: first if a node has to transmit data packet to target node, then it finds transmission of target node in transmission power table. This table stores transmission power value for each node in network, which is deleted automatically after a predefined threshold time. If a node not finding the transmission power of target node, it performs transmission power finding operation using binary search scheme. To find the target node, source node broadcasts MAC control frame with specific transmission value. Reply message to the broadcasted message is considered to be first transmission power value into transmission power table. Meanwhile, based on binary search algorithm the transmission value is replied to the target node in unicast mode. In otherwords next transmission power level will be half of current transmission power because the target node is in RF range of current power, so it is reduced by half of current power. If a reply packet is not received after the broadcasting of test packet, the transmission power value is doubled to original one.

### *F. COMPOW Protocol*

Common Power protocol finds the common transmission power between two nodes in order to maintain bi-directionality between any pair of communicating nodes in a MANET [31, 32]. If common transmission power $P_i$ is too low, a node is reachable to fraction of nodes. $P_i$ is very high results in high energy consumption. With high transmission power a node is able to reach directly to other nodes. Therefore the $P_i$ value must be optimal which value is small but preserve connectivity of a network. The major drawback of COMPOW is its significant message overhead. It also tends to use higher power if nodes are unevenly distributed.

### *G. LEAR Protocol*

Localized Energy Aware Routing protocol modifies the route discovery procedure of DSR protocol for balancing energy consumption in MANET [33]. In DSR each node appends its identity to the header of route request message and forwards it to its destination. Intermediate nodes participate in path finding procedure. In LEAR, each node decides where to forward the route-request message to its neighbor or not based on its residual energy, $E_r$. When the value of $E_r$ is higher than the threshold value $E_{hr}$, then it forward the route-request message, otherwise it drops the message and does not participate in route finding procedure. The destination node receive route request from nodes having higher battery level.

### *H. CMMBCR Protocol*

Conditional Max-Min Battery Capacity Routing protocol uses the threshold concept as in LEAR to find the route to destination [34]. However in CMMBCR route having minimum power is selected if the nodes from the source-destination pair have the larger remaining battery power than the threshold value. If all the nodes of routes having the battery power less than the threshold value then max-min route is selected.

### I. DEAR Protocol

Device and Energy Aware Routing protocol explains the usage of device awareness to enhance energy efficiency in the routing [35]. A node is assumed to be device aware if it is powered by two states: Internal battery power, and External power source. It assumes the cost of a node powered by external source is zero. The packets can be redirected to the powered node for power saving operations. An externally powered node has rich resource of power. It is capable of increasing its transmission power to a higher level so that it is easily reachable to any desired node in network in one hop distance. DEAR provides power saving by eliminating a number of hops which increases system life time, also average delay in packet receiving is minimized.

## VI. CONCLUSIONS

In order to facilitate communication within MANET an efficient routing protocol is used to discover routes between two nodes. Node's transmission power will determine the set of neighbors to which node will communicate. Transmission power of a node is directly proportional to the battery power. To conserve total energy of a network; transmission power should be adjusted in such a way so that overall connectivity of a network is maintained and at the same time network lifetime can be increased. In this chapter we have given a review of energy efficient protocol based on efficient utilization of transmission power. Our future work includes proposing a new power efficient transmission power control mechanism in the direction of conserving network power.

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**Suchismita Rout:** Mrs. Suchismita Rout is currently working as Assistant Professor in Computer Science and Engineering department in Silicon Institute of Technology, Bhubaneswar, Odisha, INDIA. She has done her M.Tech in Computer Science and Engineering department from NIT, Rourkela under the guidance of Prof. Ashok Kumar Turuk and Prof Bibhudatta Sahoo. She is a member of IEEE, CSTA, IAENG, ACEEE and IACSIT. She is also working as a JRF in project titled "Energy aware protocol for wireless Networks" sponsored by DIT, Government of India. She has 3yrs of teaching experience and assists in teaching activity in NIT, Rourkela. Her area of interest is Wireless Networking, Ad hoc Network, Sensor Network.

**Ashok Kumar Turuk:** Prof. Ashok Kumar Turuk is currently working as Head of the department in the Department of Computer Science & Engineering at National Institute of Technology, Rourkela. He received Phd from IIT, Kharagpur and M.E from NIT, Rourkela, Odisha, INDIA. Prof. Turuk has extensive industry and academic experience. His technical interests include Computer Networks, Computer Architecture, Mobile Computing, and Optical Networks..

**Bibhudatta Sahoo:** Prof. Bibhudatta Sahoo has 20years of Teaching Experience in undergraduate and graduate level in the field of computer Science & Engineering. Currently, he is Assistant Professor in the Department of Computer Science & Engineering, NIT Rourkela, INDIA. He teaches Compiler Construction, Data structures, algorithm Analysis and design, Advance Operating Systems, and Distributed Computing. His technical interests include performance evaluation methods and modeling techniques distributed computing system, networking algorithms, scheduling theory, cluster computing and web engineering.