

# Energy Efficient Routing Protocols for Mobile Ad-Hoc Networks

Rupali Mahajan, Rupali Jagtap

**Abstract-** *Ad hoc on demand distance vector routing protocol is specially designed for mobile ad hoc networks with reduced overhead using Expanding Ring Search technique. But energy consumption should also be considered in MANET due to battery constrain of the nodes. In this paper, we propose an energy efficient route discovery process for AODV based on ERS. Our approach saves energy of the nodes by avoiding the redundant rebroadcasting of the route request packets. The relaying status of the node is decided based on the broadcasting of its RREQ packets by its neighbors. And it helps in reducing routing overhead incurred during the route discovery process. Simulations are performed to study the performance of Energy Efficient AODV (E2AODV) protocol using GloMoSim, the Global Mobile Simulator. This E2AODV reduces energy consumption by 75-85% compared to AODV. It also reduces routing overhead of around 65-75% and there by reduces 60-70% collisions*

**Index Terms-**Mobile Ad-hoc Networks, Ad-hoc On-Demand Distance Vector Routing Protocol, Expanding Ring Search, Energy consumption.

## I. INTRODUCTION

Networks are classified into two main types based on Connectivity, wired and wireless networks. A wireless network provides flexibility over standard wired networks. Only with the help of wireless networks, the users can retrieve information and get services even when they travel from place to place. The single-hop and multi-hop Mobile Ad-hoc Networks (MANET) are the two major classifications of wireless networks. Base stations are used in single-hop networks to accomplish communication between nodes. MANETs [1] are infra structure-less, self organizing networks of mobile nodes without any centralized administration like base stations. The communication between nodes is accomplished via other nodes which are called intermediate or forwarding nodes. So there is a need of a routing procedure between nodes. And hence the routing protocol plays a major role in MANET.

The routing protocols in MANET are mainly classified using their routing strategy and network structure. [2]. Flat routing, hierarchical routing and geographic position assisted routing are the three major classification of routing protocols based on the network structure. Based on routing strategy, the routing protocols are grouped as Table-driven and source initiated on-demand driven [3]. Table-driven protocols usually find routes constantly and maintain in routing table for all source-destination pairs at the expense of high routing overhead. On-demand protocols such as AODV and DSR [4]

incur less routing overhead by finding path between a source destination pair only when it is necessary.

Compared to table driven protocols, on-demand protocols utilize less bandwidth and energy consumption.

Ad-Hoc On-Demand Distance Vector Routing Protocol (AODV) [4] finds route between nodes only when it is necessary. It does not maintain topology information about all other nodes in the network. In AODV, each time the node initiates the route discovery for some destination using simple flooding for broadcasting the Route Request (RREQ) across the network. Energy efficiency is an important issue in MANETs where nodes rely on limited power and computational resource, yet are required to cooperate in all sorts of fundamental network activities including routing. So, to control the network wide broadcast of the RREQs, the source node uses the Expanding Ring Search (ERS) technique [5], which allows a source to broadcast the RREQ of increasingly larger areas of the network if a route to the destination is not found. Unfortunately, some nodes in ERS technique rebroadcast the RREQs unnecessarily. For extending the lifetime of the nodes in MANET, many energy efficient protocols have been designed. In this paper, we propose a simple but energy efficient design for AODV Routing Protocol which makes some nodes silent without forwarding the not used by any other node in the network for finding routes. Using GloMoSim [6], we evaluate the performance of our energy consumption design to AODV, which is named as Energy Efficient AODV (E2AODV), in MANET.

## II. RELATED WORK

There has been significant work on routing in MANETs [3][4]. AODV is an on-demand driven protocol which finds routes between a source destination pair only when it is required. Traditional AODV extensively uses blind flooding for forwarding the RREQ packets from source to all other nodes in the network to find route. The RREQ is broadcasted to entire network so every neighbor nodes will receive and process it. All the nodes which receive the RREQ for the first time check its routing table for route. If there is route, it unicasts the RREP neighbors. If the RREQ is not the first time, it will silently discard the RREQ. And, if the node is the destination, it unicasts the RREQ to the source. When the source node gets the RREP, it starts sending the packet to the destination. When a route has been established, it is being maintained by the source node as long as the route is needed. If any of the intermediate nodes losses connectivity, the RERR will be sent to the source and the source sends packets through the alternate paths or it will restart the route discovery process.

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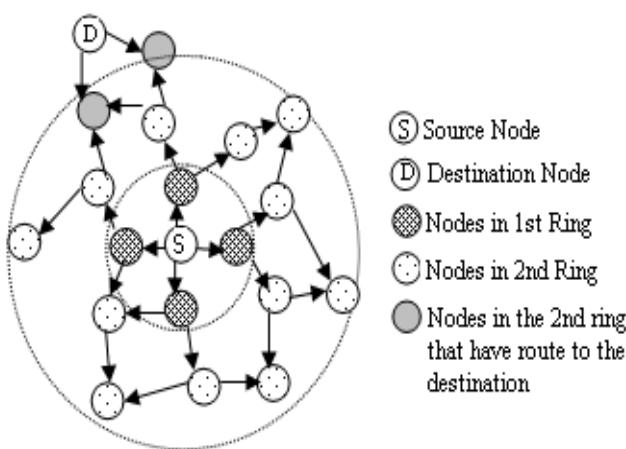
**Rupali Rahul Mahajan**, M.E (E&TC) App. Annasaheb Dange COE, AShta, Dist-Sangli, India

**Rupali Ramesh Jagtap**, Asst. Professor, Department & Telecommunication Annasaheb Dange College of Engg. & Technology, Ashta, Dist-Sangli, India

Thus the route discovery process leads to energy consumption in all nodes.

So the ERS [4] [7] is applied to AODV for route discovery process to reduce overhead and to use energy efficiently by using the Time to Live (TTL) mechanism. The ERS belongs to the reactive protocols. The goal of ERS is to find the destination or the information regarding the destination by controlled flooding of the RREQ across the network to forward the packets from source to destination. The TTL value determines the maximum number of hops that the RREQ can go through. To use the ERS, the source node sets the TTL values of the RREQ to an initial TTL\_START value and initiate the route discovery. If no reply is received within the discovery period, the source then increases the RREQs broadcast id and then re-initialize the RREQ with TTL value increased by TTL\_INCREMENT value. This process of increasing TTL value continues until the TTL\_THRESHOLD value is reached, beyond which the RREQ is broadcasted across the entire network till it reaches RREQ\_RETRIES.

In the Fig.1, when the source S wants to send packet to destination D, S has to find the path to D using ERS. The ERS starts searching for the destination by increasing the TTL value and forms the ring structured search as in the Fig.1. For simplicity, initial TTL value has been taken as 1, i.e. the S can send the RREQ to its one hop neighbors and forms the 1st ring. The node in the 1st ring does not have any information about destination and so the source again restarts the search with increased broadcast Id and TTL value. The TTL value for the 2nd ring is 3, and some nodes in the 2nd ring have route to the destination. So that nodes will unicasts the Route Reply(RREP) to the source. And when the route to D has not been found out in 2ndsearch, then the S will rebroadcasts the RREQ using this ring search technique till it finds the route to the destination.



**Figure 1. Example of ERS Technique with 20 nodes**

The ERS method has the following restrictions. If the destination node is far from the source node, and then the source node has to broadcast multiple RREQ messages. Consequently, intermediate nodes have to receive and process this message repeatedly. This leads to more consumption of energy and routing overhead. To overcome this problem, so many methods have been proposed.

In [7], based on overhearing scheme, the local topology information that has been collected during the first search at

the nodes in the 1st ring, has been used in the next search by the nodes in the 1st ring. The nodes in the 1st ring relay the RREQ only when its RREQ is forwarded by its neighbors. But when the TTL value is less than 2, its neighbors will not be able to forward the RREQ and so the nodes that are at the border will not forward that RREQ again. And so it is not efficient in finding routes.

In [8], the nodes are kept quiet based on the information received in the RREQ. In this, the nodes initial states of relaying the message will be 0 and it will be activated only when the TTL value is greater than 2. But when the TTL with less than 2 has been processed before, it will not take part in the second search. Hence it is not much efficient in finding the routes to the destination. But our approach uses the initial relay value as 1 and it has been designed effectively to handle the RREQ when its TTL value is less than 2. And so our approach does not affect the border nodes of the ring in finding routes to the destination. Since in E2AODV, the Relay value will be different for each source destination pair, one traffic will not affect the other traffic in the network. Our approach reduces the energy consumption and routing overhead even when there is mobility between nodes.

### III. E2AODV

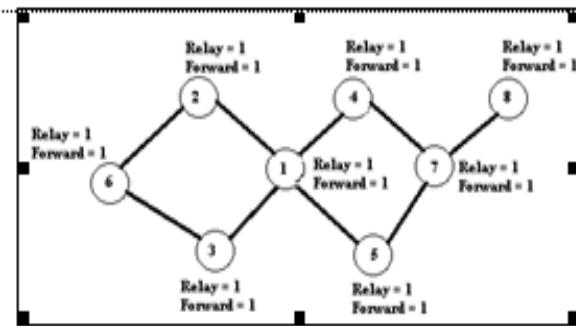
In the ERS, the source node will broadcast the RREQ to its neighbors to find route. If the neighbor nodes receive it for the first time, it will relay the RREQ. Or else it will just drop the packet. Hence there will be useful information regarding the sender and last hop, dropping the duplicate packets wastes the neighbor's information. Therefore we propose a design which helps in utilizing the information before dropping the duplicate RREQ packets to make decision about node's relay value. This helps in making some nodes silent without forwarding the redundant rebroadcast of the RREQ and thus reduces energy consumption for AODV routing protocol. This improved ERS scheme is named as E2AODV, Energy Efficient AODV.

In E2AODV, the state of the node is determined as relaying or being silent by using the Relay Value of each node in the network. Initially the Relay and Forward value of all the nodes is set to be 1, which means that it will relay the RREQ. It is shown in Fig.2. And the Relay and Forward value will be updated based on the TTL value and the P- Addr field in the RREQ packet.

The connectivity between nodes in Fig. 2 implies that it can be reachable in one hop that is within the nodes transmission range. The Relay value will be changed based on information provided in the duplicate RREQ packets. Generally in the RREQ packets, other than the hop count, source and the destination sequence number, there will be three node address fields mentioned in it.

They are the source address, destination address, last Address. Last address is the one from which it has been forwarded to this particular node. For example, consider the Fig.2, if node 2 receives a RREQ from node 1, the last address in the RREQ packet will be 1. But the node which has forwarded the RREQ to 1 will not be known to the node 2. This has been included in this E2AODV approach as predecessor address field (P-Addr) in RREQ packets. The modified RREQ packet is shown in Fig.3.





**Figure 2. Initial Relay and Forward Value in E2AODV**

**TABLE I. MODIFIED RREQ PACKET FORMAT**

Pkt	Type	Bcast	ID	Dest	Addr	Dest	Sq	Src

When a node receives a RREQ with TTL value as 0 or the duplicate RREQ, i.e. with the same broadcast ID that has been processed before, it will check for the P-Addr field in the RREQ. If that particular node address is [1]. same as the P-Addr in RREQ, then the Relay value of that node will be set to 1. It means that the node will participate in the search process of the destination. Else, the node will not participate in the route discovery process.

The relay value will be set to 0, when the RREQ for particular source Destination pair (SD Pair) is processed once. When a node receives a RREQ for first time, it checks whether the TTL is greater than 0. If zero, it will drop the message by checking the P-Add address. And if the TTL is greater than 0, it update the last address of received RREQ as P-Add and add its own address as last address and forward the RREQ to its neighbors. To make the approach more effective even when there are more traffics running simultaneously, the relay and the forward value in the nodes will be set separately for each and every SD pair. While creating network, the new table called Relay Forward Table has also been created in all the nodes with the all other tables. The fields that are present in the Relay Forward Table are given in the Fig.4.

**TABLE II. FIELDS THAT ARE USED IN RELAY FORWARD TABLE**

Source	Address	Destination	Address	Lifetime	Relay

Initially it will be set to null. And when a node receives a RREQ packet to process, the TTL value will be checked and the SD pair with the processed relay and forward value as in Fig.4 will be stored in the table then only the node will forward the RREQ. And when a node receives a RREQ, it will check in relay forward table to find out whether it is processed before or not. Then based on the Relay and forward value, it will decide whether to relay the RREQ or to just drop the RREQ. The lifetime field is added so that of the particular entry will be deleted after particular time i.e., it will be deleted when the RREP is received for that source destination or when there is any route breakage during the forwarding of the RREP or data packets. Or the entry will be automatically deleted by the MAC layer when the particular node is not participating in the forwarding of the data. This has been identified when that particular node doesn't receive any RREP. The following are the steps involved in E2AODV.

□□□ The Initial Relay and Forward value of all the nodes is Set to 1, which means it will take part in first time forwarding of the RREQ of particular source destination pair (SD pair). Then the Relay Forward junction will be called based on the TTL value of the RREQ.

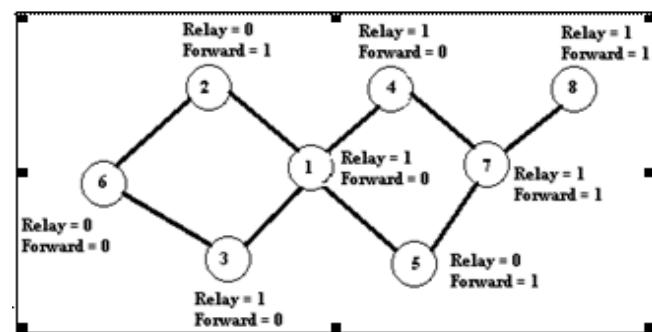
□□□ Pre-Address (P-Addr) field is added with the RREQ packet. Before initiating the RREQ, source no depends its address into its P-Add field. The intermediate nodes which are rebroadcasting the RREQ append the address of the node from which it got the RREQ packet to the RREqs P-Add field.

□□□ The Relay value will be set to 0, when an intermediate node rebroadcasts a RREQ for particular SD pair. The Forward value will also be set to 0, but only when the TTL value of the SD pair is greater than or equal to 2. Else it will remain the same.

□□□ When a node receives a RREQ with its address in P Add, then the relay value will be set back to 1 which means that the particular node's RREQ packet has been used by its neighbor nodes for finding the path. Hence the node with relay value 1 will then participate in finding the route by forward the RREQ for that SD Pair.

□□□ If both the Relay and Forward are 0, then the node will not forward the RREQ for that SD pair.

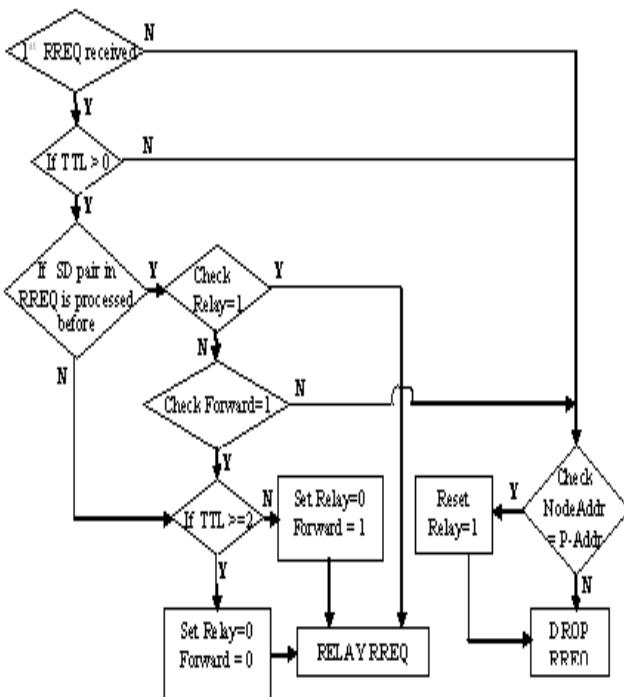
□□□ Only if the Relay value is 0, then the Relay Forward function is called depending on the TTL value. The relay and the forward value has been reset to the initial value and that particular SD pair will be deleted from the table to provide efficiency when there is route breakage due to Mobility.



**Figure 3. Final Relay and Forward value in E2AODV**

When the node 3 in Fig.2 starts the RREQ packets to find the node 8, the relay and the forward value of the nodes will be changed based on the E2AODV. Then the nodes with the relay value as 1 will take part in the route discovery process of that SD pair. If both the relay and the forward value has been set to 0 like in node 6, it means that the node 6 will not take part in the route discovery process. The final relay forward values of the Fig.2 are shown in Fig.5. It has been done using the E2AODV. The core concept for changing the relay forward value used in E2AODV is described below with the help of flow chart in Fig.6. When the RREQ with the same broadcast id is processed before, it will be checked for its P-Addr in the RREQ packets, and based on that the node will decide whether to reset the relay value or to just drop the RREQ packet. If the RREQ node will decide whether to reset the relay value or to just drop the RREQ packet. If the RREQ contains the new broadcast id with TTL value greater than 0,

it will be checked for its relay and forward value in the Relay Forward Table that has been created for the E2AODV. Hence the Relay and Forward value for each SD pair is stored separately for particular period of time, it will not affect the other SD pair route discovery process. And even when there is need of Re-Route discovery after link breakage, these values will again be set to initial values after timeout period. The performance evaluation of E2AODV is shown in the following section .IV. SIMULATION MODEL AND RESULT ANALYSIS We used GloMo Sim; a Global Mobile Simulator which uses the parallel discrete event simulation provided by Parsec, a C based simulation language. The simulation area is a square field of 1200m x 1200m size, where nodes are placed uniformly. The random way point model is used, where each node chooses a random point and move towards that point with a random speed chosen between minimum and maximum values specified. The node then waits there for the specified pause time and continues its movement as described above. The bandwidth of shared wireless channel is assumed to be 2 MHz. The nodes use the 802.11 as MAC protocol and IP as network protocol with output queue size of 100. The transmission range of all the nodes in the network is set to be around 280m. The parameters considered for the simulation are listed in the table I And to study the performance comparison of the AODV and E2AODV, the CBR traffic of 4 packets per second, with each of 512 bytes size is used with randomly selected SD Pairs. Likewise three sets of simulation with different SD pairs of CBR traffic have been taken and the average of that is taken for Consideration. Simulations are run for 10000 seconds and each data point represents an average of 3 set of CBR traffic with 4 traffic each and for three runs with different seed values for each set of CBR traffic



**Figure 4.** Flow diagram of E2AODV

#### A. Performance Metrics:

Three performance metrics are used to evaluate the protocol Variants.

**1) Energy Consumption:** Total energy consumed for transmitting and receiving packets by all the nodes in the network.

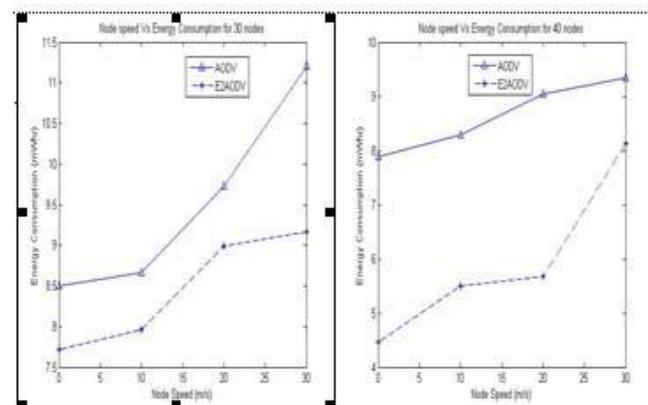
**2) Normalized Routing Load:** The ratio of the total number of packets received at the destination to the total number of RREQ packets transmitted by all the nodes in the network.

**3) Collisions:** The total number of collisions incurred at the MAC layer during the transmission of data and control packets is considered.

**B. Varying Node Mobility for Dense and Sparse**  
Performance comparison of AODV and E2AODV has been done for dense and sparse networks such as 40 and 60 and 100 nodes respectively by varying the node speed from 0 m/s to 30 m/s. Fig. 7(a, b, c & d) shows the energy consumption of node in AODV and E2AODV. Since this E2AODV shows less total energy consumption of nodes. This is because of the nodes being silent based on the Relay value. Energy consumption is generally high when the number of nodes in the network is increased. But by making some nodes silent, the E2AODV saves 75-85% of energy when compared to AODV in dense networks. And in sparse network, 60-70% less consumption of energy in E2AODV when compared with AODV.

**TABLE III. SIMULATION PARAMETERS**

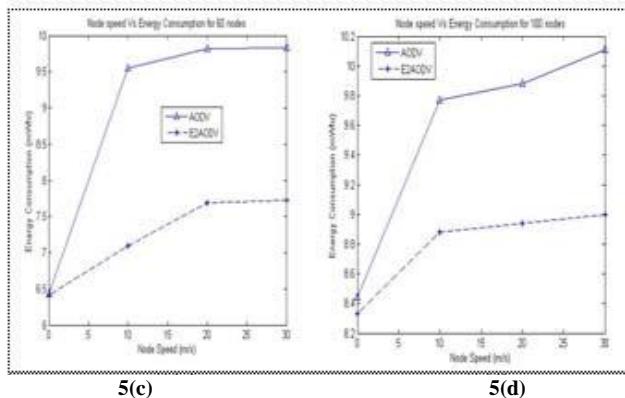
Parameters	Values
Terrain Size	(1200, 1200) Esq.
Simulation Time	10000 sec
Number of Nodes	30,40,60,100
Node Placement	Uniform
Transmission Range	280m
Bandwidth	2MHz
Propagation Model	Random Way Point Model
Minimum Speed	0 sec
Maximum Speed	0,10,20,30
Pause Time	30 Sec
MAC protocol	802.11
Network protocol	IP
Routing Protocol	AODV,E2AODV
Transport Protocol	TCP
Application	CBR



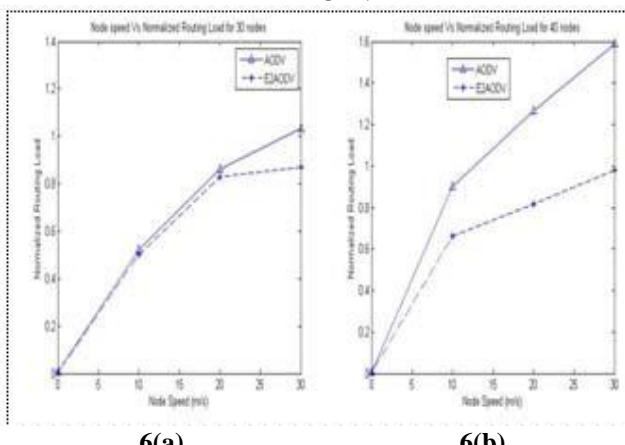
5(a)

5(b)

The normalized routing overhead incurred in AODV and E2AODV is shown in Fig. 8 (a, b, c & d). Generally when there is node movement, there will be high possibility of route breakage and so the nodes have to find the route again and again by initiating the RREQ. And hence there will be very much routing overhead. But in E2AODV, based on relay value, the redundant rebroadcasting of the RREQs are reduced and provides 65-75% less overhead than AODV.

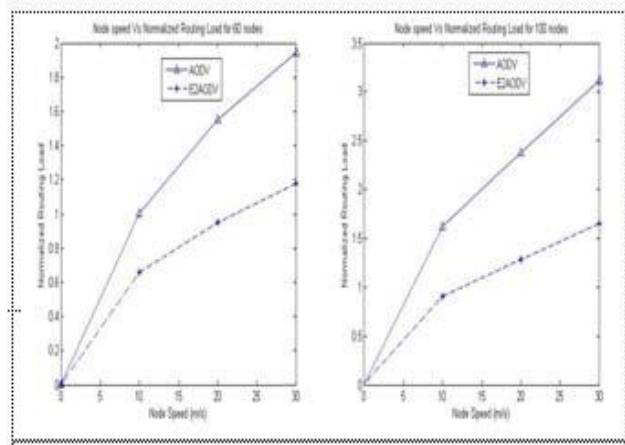


**Figure 5. (a , b , c & d) Energy consumption of AODV & E2AODV**



**6(a)**

**6(b)**



**6(c)**

**6(d)**

Due to the reduction in the RREQ packets transmitted across the network, collision has also been reduced of about 60-70%. There is much more reduction in collision in dense network when compared to sparse network. It has been shown in the Fig. 6(a, b, c & d). Generally when the node density increases collision will also get increased, but by using E2AODV, collision has also been reduced.

#### IV. CONCLUSION

The paper propose an energy efficient route discovery process for AODV based on ERS and the approach saves energy of the nodes by avoiding the redundant rebroadcasting no of the route request packets. The relaying status of the node is decided based on the broadcasting of its RREQ packets by its neighbors. E2AODV provides efficient energy consuming routing protocol with reduced routing overhead.

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#### AUTHORS PROFILE



**Mrs.Rupali rahul Mahajan** M.E(E&TC) app.  
Annasaheb Dange COE ,Ashta.Dist-Sangli.



**Ms. Rupali Ramesh Jagtap**  
Asst.Professor,Department & Telecommunication  
Annasaheb Dange College of Engg. & Technology,  
Ashta