

# DETERMINATION OF ENERGY CONSUMPTION OF NODES USING DIFFERENT RADIO ENERGY MODELS IN MOBILE AD-HOC NETWORK FOR DIFFERENT ROUTING PROTOCOLS

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**Abstract :** *Energy consumption is an important parameter in mobile ad-hoc network (MANET). As the nodes are operated by battery and there is no facility to be recharged in the devastated or remote area where MANET is applied, hence battery life-time solely decides the network life-time. Generally, there are three Radio-energy battery models are used in simulation by Qualnet :Generic ,Mica-motes and Micaz. Nodes are operated in four modes: Transmit mode, Receive mode, Idle mode and Sleep mode. There are various routing protocols are used in MANET. In this paper, we have made comparative analysis of energy consumption of various modes of operation of nodes using different protocols as STAR, Fisheye, AODV,DSR and ZRP routing protocols under three radio-energy models in physical layer with 25 nodes in grid pattern having 10 traffic loads in CBR connection.*

**Index Terms:** *Energy consumption, mobile ad-hoc network, routing protocol, radio-energy models, operating modes of node.*

## I. INTRODUCTION

Research on ad-hoc network has become very popular today as it is infrastructureless networking system which can be established on urgent basis in a devastated areas or remote places where there is no communication facility [3]. Major problem in ad-hoc network is battery life time as each node is battery operated and there is no recharging facility of the battery where it is employed. Network life time solely depends on battery life time of nodes[1]. There are continuous research effort is going on to reduce the energy consumption of nodes. Nodes are mobile hand set dedicated for operation of ad-hoc network, laptop, PDA etc[3]. Energy consumption of node depends on its percentage of time , it is in different operating modes. There are four modes of operation of a node : Transmit, Receive, Idle and Sleep[5]. In each mode, energy consumption depends on circuit to be enabled for operation. Energy consumption is minimum in sleep mode[1] as no transmit or receive operation is done in this mode as well as processor or controller stops all software operations to save power. Ideally, power consumption in sleep mode is zero. A node cannot stay in sleep mode for long time as in ad-hoc network, each node plays an important role for networking [2].

Ad-hoc network is a multi-hop networking where nodes are used as relay nodes to convey the information from source node to destination node. A node cannot go to sleep mode if it has any role as source node or destination node or intermediate relay node. After a regular interval, a node should come back from sleep state to idle state to check whether it has any responsibility for networking as relay node or addressed as destination node or it has something to be transmitted as source node[2]. If a node has no role for a certain time in idle state, then it can go back to sleep mode again for certain time to save power. If a node intentionally stays in sleep mode for a long time to save power, it is then considered as selfish node [3] which is harmful for the network. But if residual power of a node goes below its danger level, then it can discard its role as intermediate relay node and take part only as urgent service of source node or destination node to enhance network life-time. In idle state, energy consumption is less as no transmit or receive function is not done in this state [1].

Typical measurement shows, a network interface in idle mode can consume over 800mW, where it is 1000mW for receiving mode and 1300mW for Transmit mode. In sleep mode, it is 66-130mW [2]. To reduce the energy consumption, an interface must stay in sleep mode as much time as possible. According to the Specification of TR1000 Radio used as node with transmission range of 100m and transmission rate up to 115.2 Kbps, consumes 13.5 mW, 24.75 mW and 15  $\mu$ W in receiving/idle, transmitting, and sleeping states respectively[4]. To save energy, there are several energy aware protocol are used [1]. Power saving techniques as span using dominating nodes saves 50% energy by rotational co-ordinator nodes with only awake states and non-coordinator nodes with cyclic wake-sleep states[2]. Like, span, another power saving protocol, adaptive fidelity energy conservation algorithm(AFECA)/Basic Energy Conservation Algorithm(BECA) which is switching between sleep, listening and active state saves 35-45% of power[2]. The Geographical Adaptive Fidelity (GAF) algorithm is utilised to save power by shut off unused nodes [9][22]. Battery Energy Efficient (BEE) protocol calculate cost function of possible routes and chooses the route with minimum cost function [10][18].

There are several layers are used in Networking as Physical layer, Medium access control (MAC) layer, Transport layer, Network layer and Application layer[20]. Energy conservation primarily made on Physical layer but energy reduction can be possible accounting other layers [1][19]. Power-Aware Multiple Access Protocol with Signalling (PAMAS) turns off nodes when they are not receiving packets as energy for RTS/CTS (request to send/Clear to Send) is saved in MAC layer [4]. In Transmit mode, the energy consumption depends proportionately on data rates as well as some constant power of circuit which are independent of data. Hence, the model of energy for data transmission and reception is shown by the equation:

$$E = m * d + b$$

where  $d$  is the data size and  $m$ ,  $b$  are the coefficients which depends on type of communication as unicast or multicast [1][4]. Low power hardware circuit also plays a vital role to reduce power consumption of nodes [2]. An energy reduction techniques is introduced in LEACH (Low-energy Adaptive Clustering Hierarchy) [4] where nodes in a cluster shares the energy load by rotating cluster head randomly. The energy transmitted depends on  $d^2$  for short distance and  $d^4$  for long distance [4]. Hence, node can save energy if node density is more. But more node density can increase the number of hops i.e. number of intermediate nodes which requires more energy in total. Hence, observation of energy characteristics with node density is a vital parameter to be studied. In section-II, we briefly described different routing protocols. Related work is mentioned in section III. In section-IV, we have mentioned characteristics of different Radio Energy models. Simulation results are given in section -V. Conclusion and future work is mentioned in section-VI.

## II. ROUTING PROTOCOLS

Routing is the process to find a path to reach destination node from source node, which plays an important role in multi-hop mobile ad-hoc network. Generally, there are three types of routing protocols are used in MANET: Proactive (Table-driven), Reactive (On-demand) and Hybrid [9][17].

In Proactive protocol[17], each node keeps a table in its cache memory which contains the information of routing path of all nodes in the network. As the nodes are mobile in nature, hence periodic updating of table is required. Periodic updates are made by broadcasting Hello message to neighbouring nodes. In routing table, information of destination IP address, destination sequence number, hop count are kept. More destination sequence number means more updated information [9]. To choose a route to a particular destination, a node always selects a path with more destination sequence number as it is most updated information. There are three types of hello message used to neighbouring nodes: neighbour request, neighbour reply, neighbour lost depending on unidirectional, bidirectional and loss of communication with neighbouring node respectively and routing table is modified correspondingly if new node appears as neighbouring node or any neighbouring node is lost[9].

Whether any information transfer is required or not, a large power is wasted in Proactive Protocol due to periodic updating of routing table. But advantage of this protocol is no routing delay occurs as each source node has the information about the routing path to other nodes which it gets from the routing table stored in the memory of source node. There may be number of routing paths available, out of which source node selects the shortest path i.e. path with minimum number of hops to reach the destination. In Bellman Ford which is very simple proactive protocol uses this mechanism. There are lot of modification are made in proactive protocols to enhance the different parameters in routing mechanism as average jitter, End-to-End delay, Packet Delivery Ratio(PDR), Throughput etc. which are discussed in [7]. As a result a lot of Proactive protocols has been emerged as DSDV(Destination-Sequenced Distance Vector Routing), OLSR(Optimized Link State Routing), LANMAR(Landmark Ad-hoc Routing),FSR(Fisheye State Routing),STAR(Source Tree Adaptive Routing) etc[9]. Proactive protocol is also known as Table-driven Routing Protocol as routing table information plays a vital role in routing mechanism.

In Reactive Protocol[9][17], there is no information is kept in the cache memory of any node about the other node's position and routing path in the network. No regular updating is made about the location and routing path of other nodes. Node comes to active mode i.e. transmit or receive mode only when there is a necessity of information transfer. For this reason, this protocol is also called as on-demand protocol. A lot of energy is saved in this protocol as there is no need for regular updating of routing table. But routing delay is more in this protocol as source has no prior information about the destination node or intermediate relay nodes. Source node starts searching about destination node when it has to convey any information to other node. In modified reactive routing protocol such as AODV (Ad Hoc On-Demand Distance Vector Routing)[9] if source node has made any previous communication with the destination node following a particular routing path which may be kept in its memory. Source node first searches for that information. If source node gets any information about previous routing path, it tries to follow that routing path otherwise it tries for new routing path. The searching process of routing path is called route discovery.

In route discovery mechanism, source node broadcasts route request to its neighbouring nodes. Route Request (RREQ) consists of source node IP Address, destination node IP Address and number of hops[9]. Neighbouring nodes are used as intermediate nodes which relay the information towards destination node. After receiving the Route Request (RREQ), intermediate node checks whether it has any previous routing path to destination node. If intermediate node has any information about routing path of destination node, it follows that path, otherwise it retransmits the Route Request (RREQ) to its neighbouring nodes inserting its node IP address and incrementing hop count along with the received information from the source node which contains source node IP address and destination node IP address. This process goes on till the destination node is detected. Any node after receiving route request, checks whether its node IP address matches with destination IP address of the received information. When destination node receives the route request, it sends the Route Reply (RREP) following the reverse path of Route Request

(RREQ). Route Request (RREQ) is sent in broadcast mode where Route Reply (RREP) is sent in unicast mode. If source node receives multiple route reply, it chooses the path with shortest distance i.e. path having minimum number of hop count. Once, route is discovered by source node, it starts communication with destination node. Along with route discovery another mechanism is used in reactive protocol that is route maintenance. If source node fails to communicate in any intermediate stage during communication, source node tries to recover the route which is known as route maintenance following the same mechanism used in route discovery. It happens as any intermediate node may change its position as nodes are mobile in nature in ad-hoc network. DSR (Dynamic Source Routing), AODV (Ad Hoc On-Demand Distance Vector Routing), LAR (Location-Aided Routing), TORA (Temporarily Ordered Routing Algorithm) are example of Reactive protocols [9].

In hybrid protocol, total network area is divided into some segments. For intra-segment communication between nodes, we use proactive protocols and for inter-segment communication, we use reactive protocols. ZRP (Zone Routing Protocol) is a example of hybrid protocol. There are also other protocols used as cluster based hierarchy[1], geographical location based using GPS mechanism [9] and energy saving mechanism[10].

### III. RELATED WORK

Laura Marie Feeney et. al. investigated energy consumption of a Wireless Network Interface in an Ad Hoc Networking Environment by series of experiments and obtained detailed measurements of the energy consumption of an IEEE 802.11 wireless network interface operating in an ad hoc networking environment [1]. He also searched Power Save Protocols by using Cyclic mode of Wake and Sleep State[2]. Cintia B. Margi et. al.[4] evaluated energy consumption in Ad-hoc Network using simulator as Qualnet /GloMoSim in different operating modes as Transmitting, Receiving, Over-hearing and Ideal mode using AODV and DSR Routing Protocol. Laura Marie Feeney et. al.[5] analysed the performance of an Energy Consumption Model using AODV and DSR Routing Protocol in ns-2 simulator for Mobile Ad Hoc Networks. Niranjana Kumar Ray et. al.[11] proposed an energy conservation technique called Location Based Topology Control with Sleep Scheduling for ad hoc networks using Qualnet Simulator and showed that the energy consumption is lower with increase in the network lifetime and higher throughput in the proposed scheme. Rohit Sangwan et. al. [12] has made Energy Consumption Analysis of Ad hoc Routing Protocols for Different Energy Models in MANET. Shridhar Kabbur et.al.[13] simulated Impact of CBR Traffic on Energy Consumption in MANET. Laura Marie Feeney et. al.[14] presented a comparative evaluation of several IEEE 802.11 and IEEE 802.15.4 simulators. Christian Rohner et.al.[15][16] evaluated battery models and discharge characteristics. Natalia Vassileva et.al.[21] made a Survey of Routing Protocols for Maximizing the Lifetime of Ad Hoc Wireless Networks.

### IV. RADIO ENERGY MODELS

Energy saving is an important issue in battery operated wireless communication system. As energy of battery is finite, hence life time of ad-hoc network is finite. Major energy is consumed for transmission of bits. If we can calculate the energy required per bit for transmission, we can easily get number of bits a node can transmit in its total life time. Continuous research is going on how we can minimize power required to transmit each bit. Obviously, maximum time of sleep mode increases lifetime of a node. But, in ad-hoc network, we use multi-hop communication where nodes are used as intermediate relay nodes. Hence, sleep mode of node makes the network unhealthy [1]. There are three types of Radio energy models are used for simulation of ad-hoc network in practice which are in-built in Qualnet simulator. These are Generic, Mica-motes and MICAZ which are discussed and compared below. There is another option as User Defined where a new radio energy model can be developed and can be imported from a file. The Block diagram of a Radio Energy dissipation model [6] is shown in below in Fig.1.

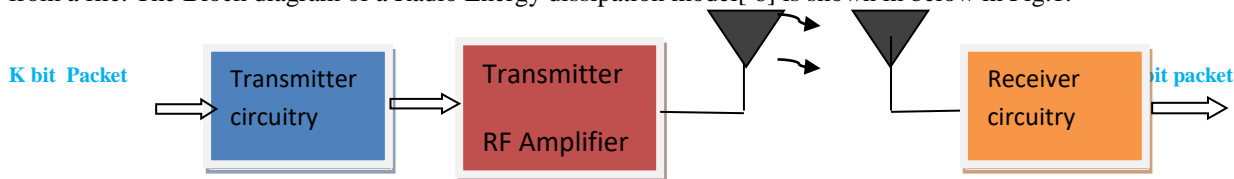


Fig.1: Radio Energy Dissipation Model

Total energy consumption of a node,  $E_{total}$  can be divided into four components:

$$E_{total} = E_{transmit} + E_{Receive} + E_{idle} + E_{sleep} \text{ -----(1)}$$

Energy consumption for transmitting k bit of data packet,  $E_{transmit} = P_{on} * T_{transmit} = (P_{tran-sig} + P_{tran-ckt}) * T_{transmit}$  -----(2)

Where  $P_{on}$  is the total power in transmit mode which comprises of Transmitted signal power,  $P_{tran-sig}$  and Circuit power consumption,  $P_{tran-ckt}$  of total transmit signal path including RF amplifier. RF amplifier is obviously power amplifier of class A (linear) or Class B Push-Pull, Class C, D or E (non-linear). Efficiency of power amplifier changes from 25% for single sided class A to 100% for Class C and higher classes. Circuit for modulation may be analog and digital. Circuit path of Transmitter for analog modulation is shown below[6] in Fig.2:

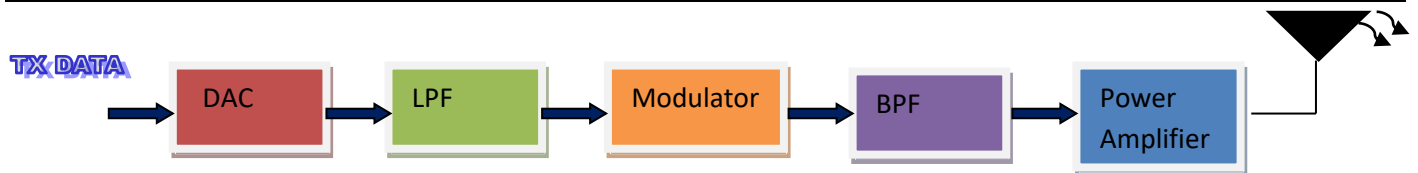


Fig. 2: TX signal processing path

For analog modulation QAM (Quadrature Amplitude Modulation) is used for sending both audio and video signal (if necessary), Whereas for digital modulation, MFSK (M-ary FSK) is used. For digital modulation: DAC (Digital to Analog converter), LPF (Low Pass Filter) are not required. Hence, Power consumption due to transmitter circuit,  $P_{\text{trans-ckt}}$  will be reduced for digital modulation.

Power consumption of power amplifier,  $P_{\text{amp}} = \alpha P_{\text{trans-sig}}$  where  $\alpha = (\beta/\mu) - 1$  [6] -----(3)

Peak to Average Ratio(PAR),  $\beta$  is dependant of modulation techniques and associated constellation size and  $\mu$  is the drain efficiency of RF power amplifier[6]. Value of  $\mu$  varies on classes of power amplifier. For Class A power amplifier  $\mu=0.35$  where  $\mu=0.75$  for Class B and higher classes of power amplifier (class C,D,E)[6].

The block diagram of receiver [6] is given below in Fig.3:

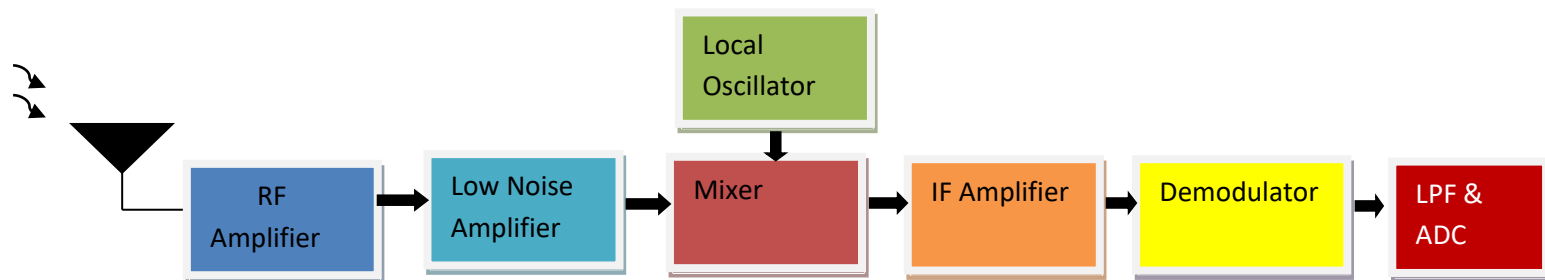


Fig.3: RX Signal Processing Path

ADC is not required in receiver circuit for digital modulation. For receiver, total power is required for circuitry only, no power is required for signal. As a result, power consumption for receiver is less than power consumption of transmitter. Packet delivery ratio (PDR) plays an important role for efficiency of ad-hoc communication system. If PDR is less than 100%, it means some data packets transmitted but lost in the path which indicates unnecessary power wastage in transmission of data packets. There are three energy models are used: Generic, Mica-motes and MICAZ. Time consumed in Transmit mode, Receive mode, Idle mode and Sleep mode in different radio energy model is an important factor. Standard value of power consumption of different components of circuit in Transmitter and Receiver is given below [6]:

Power at Mixer stage,  $P_{\text{mixer}} = 30.3\text{mW}$ .

Power at RF amplifier and IF amplifier,  $P_{\text{IFA}} = P_{\text{RFA}} = 3\text{mW}$ .

Power at LNA,  $P_{\text{LNA}} = 20.0\text{mW}$ .

Power at Filters in Transmitter and Receiver,  $P_{\text{LPF}} = P_{\text{BPF}} = 2.5\text{mW}$

Power at modulator and demodulator,  $P_{\text{mod}} = P_{\text{demod}} = 50\text{mW}$ .

Power at DAC in transmitter,  $P_{\text{DAC}} = 15.4\text{mW}$ .

Power ADC in receiver,  $P_{\text{ADC}} = 14\text{mW}$ .

The parameters and specifications of three Radio Energy Models as Generic, Mica-motes and MICAZ are given below:

#### Generic Radio Energy Model :

This model is derived from the circuitry and equations discussed above i.e. type of modulation, classes of power amplifier used etc. It calculates power consumption of Radio in different power modes as Transmit, Receive, Idle and Sleep. The parameters of Generic Radio Energy Model is given below to calculate accurately power consumption from battery:

- 1. Amplifier drain efficiency( $\mu$ ):** It depends on class of power amplifier used in transmitter. It is 35% for Class A power amplifier and 75% for higher classes of power amplifier.
- 2. Peak to Average Power Ratio(PAR) $\beta$  :** It depends on type of modulation done. It is 1 for digital modulation and more than 1 for analog modulation.
- 3. Power Supply Voltage ( $V_{\text{dd}}$ ):** It varies 3V to 6V.
- 4. Idle Mode Power Consumption,  $P_{\text{idle}}$ :** It calculate the power consumed in inactive state i.e. without transmission or reception.
- 5. Sleep Mode Power Consumption,  $P_{\text{sleep}}$ :** The default value is taken as 0mW.

#### Mica-motes Radio Energy Model:

It measures the current in transmit mode with various power levels and in receive mode. It is pre-configured Radio Energy model whose radio energy consumption is specified as given below[6]:

Components	Mode	Currents(in mA)
Radio	Receive	7.00
	Transmit(in dB)	
	-20	3.70
	-19	5.20
	-15	5.40
	-8	6.50
	-5	7.10
	0	8.50
	+4	11.60
	+6	13.80
+8	17.40	
+10	21.50	

**MICAZ Radio Energy Model:**

It is another Radio Energy Model which is preconfigured and power consumption in different mode of operation is specified as given below [ 6]:

Description Of Power Mode	Symbol	Micro-controller Unit(MCU) Mode	Radio Mode	Power @3V
Power in Transmit Mode	$P_{Tx}$	Active	Tx (0 dbm)	48.0 mW
		Active	Tx(1 dbm)	45.0 mW
		Active	Tx(3 dbm)	42.1 mW
		Active	Tx(5 dbm)	39.1 mW
		Active	Tx(7 dbm)	36.0 mW
		Active	Tx(10 dbm)	32.9 mW
		Active	Tx(15 dbm)	29.8 mW
		Active	Tx(25 dbm)	26.6 mW
Power in Receive Mode	$P_{Rx}$	Active	Rx	56.5 mW
Power in Combined Circuit Active Mode	$P_{CCA}$	Active	CCA	55.8mW
Power in Idle Mode	$P_{Idle}$	Active	Idle	2.79mW
Power for Micro-controller Circuit Unit	$P_{MCU}$	Active	Sleep	1.50mW
Power in Sleep Mode	$P_s$	Sleep	Sleep	30 $\mu$ W

**V. SIMULATION RESULTS**

Simulation is done with the Qualnet5.0.2[8]. For our work, we have taken 25 nodes arranged in Grid pattern with 10 traffic load in CBR connection as shown in fig.4. Snap-shot of simulation is shown in Fig.5. From Fig.4, we see nodes 1,6,8,9,13,16,18,21,23, 25 are used as source nodes which are connected to nodes 7,18,19,20,22,3,24,4,5,11 as destination nodes in CBR(Constant Bit Rate) mode.

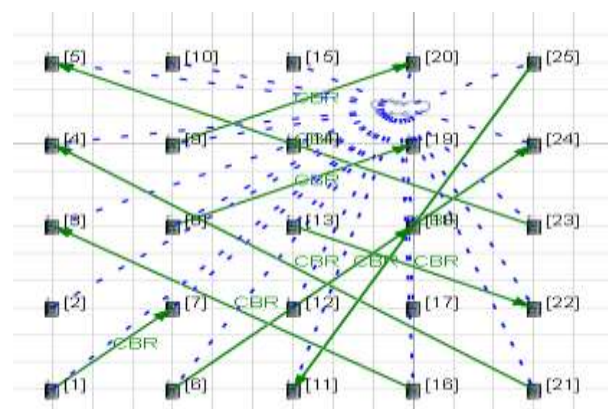


Fig. 4: Screen Shot of node placement pattern.

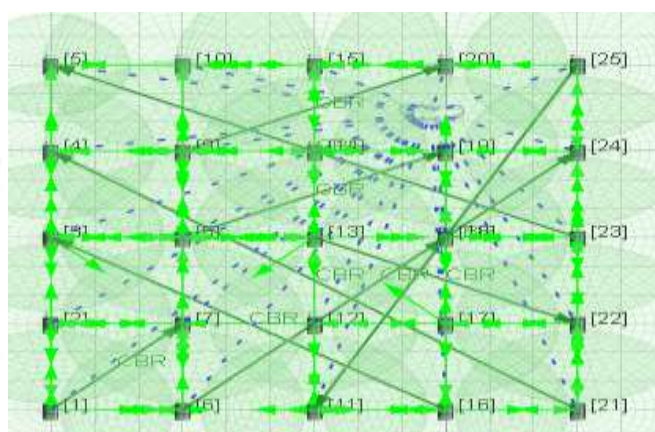


Fig5. Snap shot of simulation of the arranged node pattern.

Simulation characteristics are given in Table1 below.

Table1: Simulation Characteristics

Serial No.	Parameters	Values
1	Simulator	QualNet Version 5.0.2
2	Terrain Size	1500 Meter x 1500 Meter

3	Antenna model	Omnidirectional
4	No of nodes	25
5	Radio Type	802.11b
6	Propagation Model	Two Ray Ground
7	Channel Frequency	2.4 GHz
8	Traffic Source	CBR
9	Pattern of arrangement	Grid
10	Antenna Height(meters)	1.5
11	Data Rate	2Mbps
12	Antenna Gain(dB)	0.0
13	Transmission Power at 2Mbps( dBm)	15.0
14	Receive Sensitivity at 2 Mbps (dBm)	-91.0
15	Noise Factor(dB)	10
16	Performance Metrics in Physical Layer	Energy consumed in Transmit mode, Received mode, Idle mode
17	Radio Energy Model	Generic, Mica-motes, MICAZ
18	Mobility Model	Random Way Point
19	Routing Protocols	Proactive: STAR,FISHEYE Reactive : AODV, DSR Hybrid : ZRP
20	Power Amplifier Inefficiency Factor	6.5
21	Transmit Circuitry Power Consumption(mW)	100.0
22	Receive Circuitry Power Consumption(mW)	130.0
23	Idle circuitry power consumption( mW)	120.0
24	Sleep circuitry power consumption( mW )	0.0
25	Supply voltage(volt)	6.5
26	Simulation Time	60 Seconds.

The analysis of Simulation output is shown in following graphs. 25 nodes arranged in Grid pattern with 10 Traffic loads in CBR as shown in Fig.4 are simulated using Qualnet 5.0.2 with three different Radio Energy Model i.e. Generic, Mica-motes and MICAZ with various Routing Protocols : Two from Proactive i.e. Fisheye and STAR , Two from Reactive i.e. AODV and DSR , one from Hybrid i.e. ZRP. The Snap Shot of Simulation is shown in Fig.5. The analysis are made on following parameters under Three Radio Energy Models of Five Routing Protocols:

1. Average Energy Consumption of Nodes in Transmit Mode(Fig.6)
2. Average Energy Consumption of Nodes in Receive Mode (Fig.7)
3. Average Energy Consumption of Nodes in Idle Mode (Fig.8).
4. Average Percentage of Time of Nodes in Transmit Mode (Fig.9).
5. Average Percentage of Time of Nodes in Receive Mode (Fig.10).
6. Average Percentage of Time of Nodes in Idle Mode (Fig.11).
7. Average Value of Received Signals with Error in Nodes (Fig.12).
8. Energy Consumption and Percentage of Time of Nodes in Sleep Mode (Fig.13).

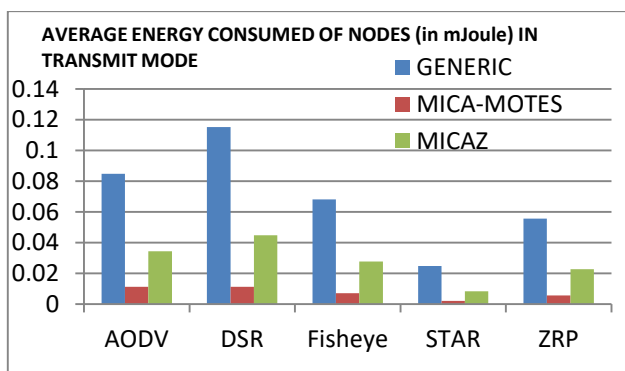


Fig.6: Comparison of Average Energy Consumption of Nodes In Transmit Mode Under Different Energy Models With Various Routing Protocols.

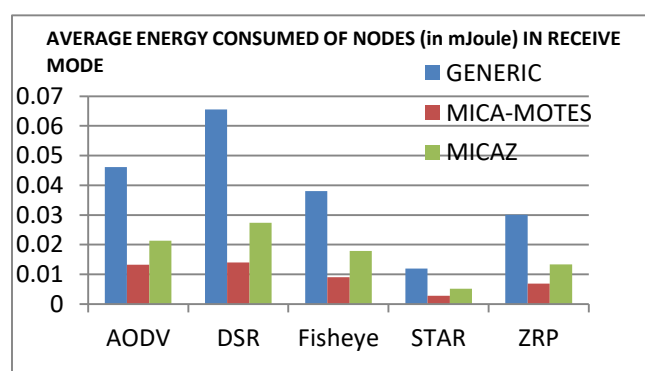


Fig.7: Comparison of Average Energy Consumption of Nodes In Receive Mode Under Different Energy Models With Various Routing Protocols.

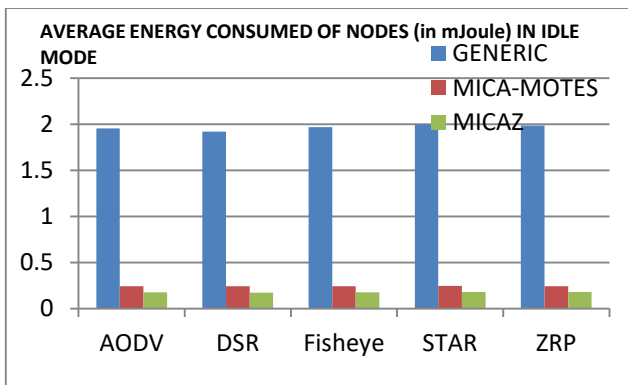


Fig. 8: Comparison of Average Energy Consumption of Nodes In Idle Mode Under Different Energy Models With Various Routing Protocols.

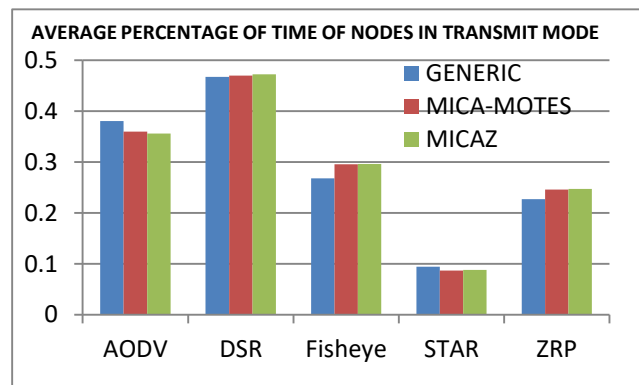


Fig. 9: Comparison of Average Percentage of Time of Nodes In Transmit Mode Under Different Energy Models With Various Routing Protocols.

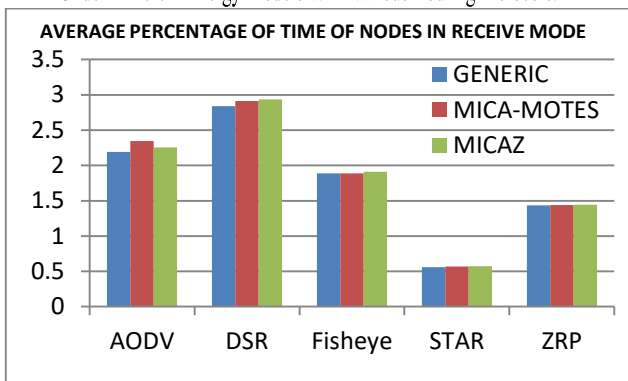


Fig. 10: Comparison of Average Percentage of Time of Nodes In Receive Mode Under Different Energy Models With Various Routing Protocols.

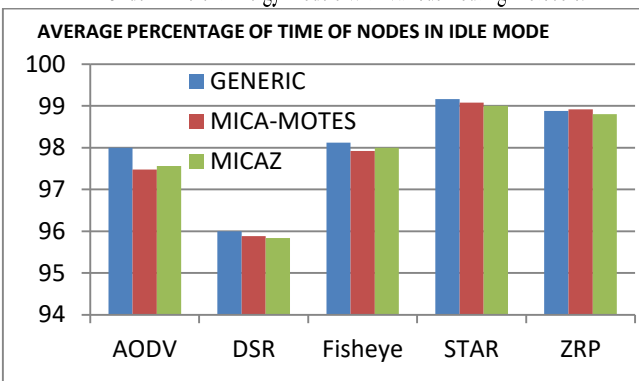


Fig. 11: Comparison of Average Percentage of Time of Nodes In Idle Mode Under Different Energy Models With Various Routing Protocols.

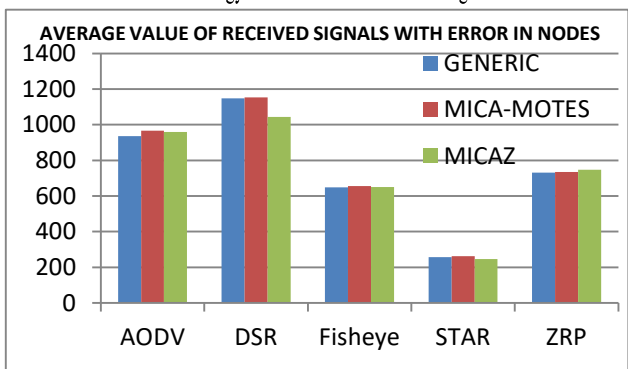


Fig. 12: Comparison of Average Percentage of received signals with Error in Nodes Under Different Energy Models With Various Routing Protocols.

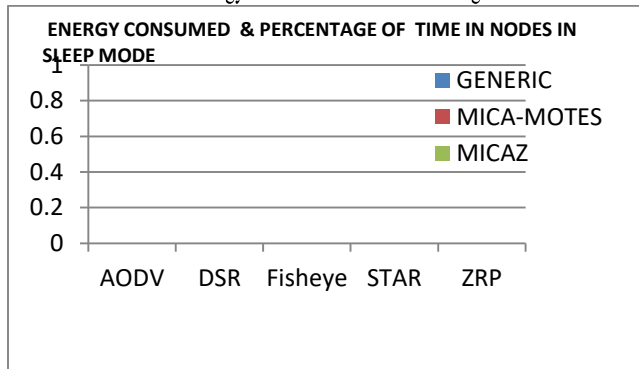


Fig. 13: Comparison of Energy & Percentage of Time of Nodes in Sleep Mode Under Different Energy Models With Various Routing Protocols.

**VI. CONCLUSION & FUTURE WORK**

We get a lot of information, by observing the graphs of Fig.6 to Fig.13. From Fig. 6 & Fig. 7, we see in Generic Radio Energy Model, Consumed Energy in Receive Mode is around 50% of Energy Consumed in Transmit Mode for each Routing Protocols, whereas in Mica-motes Energy Consumption both in Transmit and Receive mode are nearly same for each type of Routing Protocol and in MICAZ Energy Consumption in Transmit mode is nearly 1.5 times of Energy Consumption in Receive Mode in each Routing Protocol. Mica-motes and MICAZ Consumes around 10% and 30% of Energy respectively in comparison with Generic Energy Model in Transmit mode (Fig.6). Both in Transmit and Receive Mode, DSR consumes maximum Energy which is around 1.4 times of AODV, around 1.8 times of Fisheye, around 2.1 times of ZRP and around 6 times of STAR in all Radio Energy Models (Fig.6 & Fig.7). From Fig.8 we see, Energy Consumption in Ideal mode remains nearly unchanged irrespective of the Routing Protocol for each type of Radio Energy Model. Energy Consumption in Ideal Mode(Fig.8) for Generic Radio Energy Model is around eight times of Mica-motes Radio Energy Model and around eleven times of MICAZ Radio Energy Model.

From Fig.9, Fig.10 and Fig.11, we can say, Percentage of Time in Transmit Mode, Receive Mode and Ideal Mode in individual are nearly same for all Radio Energy Model under a specific Routing Protocol. Percentage of Time in Receive Mode is nearly six times of Percentage of Time in Transmit Mode for each Routing Protocol(Fig.9 & Fig.10) for all Radio Energy Models. Percentage of Time in Idle Mode varies around 96% to 99% for various Routing Protocols in every Radio Energy Model, which is maximum for STAR Routing Protocol and Minimum for DSR. From Fig.6, Fig.7 and Fig.8 we get Energy Consumption in Transmit, Receive and Idle mode respectively. Similarly from Fig.9, Fig.10 and Fig.11, we can calculate Time duration in

Transmit, Receive and Idle Mode Respectively. Hence, we can easily calculate power consumption for Transmit, Receive and Ideal Mode in all Radio Energy Model using all Routing Protocols using all these graphs. From Fig.12, we observe with surprise, Average Received Signals with Error in Nodes which is a direct measurement of wastage of power, remains nearly same for all Radio Energy Models in each Routing Protocol. From above all graphs, we can easily say STAR Routing Protocol is best in all respects, followed by ZRP as second, followed by Fisheye as Third, followed by AODV as Fourth and DSR is the worst performer. Total Energy Consumption i.e. summation of Energy Consumption in Transmit Mode, Receive Mode and Idle Mode is least in MICAZ Radio Energy Model. Fig.13 declares no time as well as no Energy is utilised in Sleep Mode. In future work, we can save energy if any algorithm is introduced to keep nodes in sleep mode in cycle to enhance life-time of the network. The effect of variation in node density and traffic load on energy consumption is another scope of observation as future work.

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