Optimized Power Efficient Routing in Ad-hoc Networks

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Energy-efficient routing in Ad-hoc networks is an important research issue since it directly impacts network lifetime. This paper proposes a novel optimmzed power efficient routing algorithm (OPERA) considering the network parameters like node density, power consumption, traffic congestion and node status. The proposed work ranks the network communication parameters based on different traffic congestien zones like maximum, moderate and minimum, using Analytical Hierarchy Process (AHP) and selects optimal path. The OPERA is adaptive and power efficient. A simulation study is performed to compare the performance of OPERA with AODV protocol. Our results indicate that OPERA consumes less power than AODV.

Keywords: Optimized power efficient routing algorithm (OPERA), Ad-hoc network; Node Density (ND), Node Status (NS) Traffic Congestion (TC), Power Consumption (PC), Analytical Hierarchy process (AHP).

1. INTRODUCTION

An ad hoc network is a collection of nodes which may be static or a temporary network without the pre-knowledge of any centerlized management administration or standard support services, which are regularly available or the conventional wireless networks. Ad-hoc networks [Sonawalker and Havinal 2013] do not rely on any pre-established infrastructure and can therefore be deployed in places with no base stations unlike in case of mobile networks.This is useful in disaster recovery situation environments and places with non-existing or damaged radio communication system, where quick and fast deployment of a network is needed for cormmunication.

Since most of the nodes and devices on ad hoc network are battery operated, and generally these networks are of large size, saving battery life is an important design issue. Hence, designing power efficient protocol for saving the battery life in ad hoc network is a challenging task. Related work by various researchers focuses on the use of low power hard disks, low power analog-to-digital and digital-to-analog converters, high capacity batteries, low power analog or digital ICs, which are adequate to increase the life time of the networked systems.

From the existing research in this field, we observe that some of previous works are based on graph theoretical and computational geometrical techniques, which are further based on a simplified model. The others are based on building simulation or real system, based on electronics engineering methodologies.However, the power model in the former approaches is too simple and assumes that every node of network must know the power level of all other nodes. Some simulation models even require location information of all the nodes available in the network. However, power consumption also depends upon key communication network parameters, can be determined under different data traffic congestion zones. These parameters include node density (ND), traffic congestion(TC), power consumption (PC) and node status (NS). These parameters can be ranked using Analytical Hierarchy Process (AHP) [Saaty and Thomas 1990] to find the cost function of all network nodes, which would in turn help in selecting the optimal power efficient route.

Power optimization is a vital desgin issue in any Ad hoc network. This work is an attempt to use the AHP technique considering the key network parameters at different traffic congestion sizes to select the optimal path with less power consumption.

1.1 Related Work

In ad-hoc networks power can be saved at different levels. Many researchers proposed different techniques to reduce power consumption or save the battery life.

For the study of wireless ad hoc networks, power efficiency routing always held an important place for consideration. In order to achieve this goal, multiple routing paths between the source and destination are desirable. And for this even some of the traditional routing schemes have been considered in wireless ad hoc networks. In mostly all routing protocols [Dillip Kumar and Vijay Kumar 2008; Benamar K. and M.H. 2008; A.M. Akhtar and Aghvam 2012; W Chee-Wah Tan and Cheg 2012; Chen and Baras ; Ganesh and Amutha 2013; Sinha and Braman 2012], the determination of power optimized path between source and desnination node is a very important key, taken under several constrains. But, the major drawback of these traittional algorithms being used here is the occurrence of difficulty in case of large number of nodes in the network, as it is difficult to find a suitable solution while ensuring less power consumption.

In [Dillip Kumar and Vijay Kumar 2008] author has concluded that battery life is dependent upon a) residual power capacity, b) transmission power consumption c) reception power consumption , and the total power consumed is given by the sum of all. The algorithm is used here to find the optimized route for saving the power consumpnion by guaranteeing the transmission of network data packets, which in turn depends on the residual power capacity of each node along the route.

The desired goal of power efficiency is obtained by protocols based on power management, through the use of two channels, one for control and the other for data. For example, RTS/CTS signals are transmitted via control channels and the data via data channels. The protocol that facilitates this technique ia known as Power Aware Multi Access Protocol (PAMAP) [Benamar K. and M.H. 2008]. Here, the node sends an RTS message over the control channel, after becoming ready to be transmitted, where it waits for CTS. If CTS message is not received within a stipulaled time, the node enters to the power off mode, and sends a busy tone sign over the control channel to its neighbor. After turning to active state, the node is enabled and the node can now transmit data over the data channel. The converse is also applicable, i.e. once CTS is received, and the node transmits the data packet over the data channel.

In congested areas, the network nodes are generally situated at very high altitudes and they may not have directive lines due to multicast fading effects which again results in high power consumption. The best possible solution to this problem is Adaptive Power Routing Algorithm (APRA) [A.M. Akhtar and Aghvam 2012; Chen and Baras]. APRA is an optimized algorithm, based on the pre-location knowledge of the network nodes and also localized fading effects on each node. This technique uses two matrices to select the optimal intermediate forwarding nodes. The source node logically decides whether it will send the data directly to destination node or through the intermediate nodes, using the parameter of characteristic distance so as to save the power being consumed.

The use of better power efficient optimized route has been achieved with the help of the commonly used genetic algorithm [Beatrice Ombuki and Hanshar 2006; Pushpavalli and Natarajan ; Acampora and Vasilakos 2010; Kulturel-Konak and Coit 2003; Wook and Ramakrishna 2002], which comprises optimization techniques based on the principles of evolution theory. This algorithm, because of its potential as an effective optimizing technique for complex problems, has received considerable attention. It has wide application in industrial engineering such as fuzzy systems, bio intelligent systems, as well as ambient intelligent applications.

This literature survey devotes full attention to how these various techniques/protocols can be used to select the energy efficient route to save battery life or to increase the network life time. In this paper we put forward an adaptive optimized power efficient routing algorithm considering real key network parameters using AHP and further selecting an optimal path.

2. PROBLEM FORMULATION AND METHODOLOGY

A typical Ad-hoc network can be considered to be made up of n nodes. Network parameters like node density (ND), traffic congestion (TC), node status (NS) and power consumption (PC) have been considered for cost estimation of each node. The main objective of proposed work is to find optimal path with minimum energy consumption, considering these key network parameters, normalized by ranking them from 1 to 8 using AHP modeling. As Analytical Hierarchy Process [Saaty and Thomas 1990; Flair 1995] is a method for comparing a list of objectives or alternatives. When used in the system enginenring process, AHP can be a powerful tool for comparing alternative design concepts. AHP is also a comprehensive, logical and structured framework.

We assume four different traffic congestion zones as maximum, moderate, minimum and no congestion depending upon size and data rate being communicated between source and destination node pairs. The algorithm will switch to a specific congestion zone and will find out the optimal path by minimizing the cost function. The cost function depends upon the traffic load, which is measured by using the performance matrix shown in the equation 1 below.

$$\Delta = \begin{bmatrix} \alpha 1 & \beta 1 & \gamma 1 & \varphi 1 \\ \alpha 2 & \beta 2 & \gamma 2 & \varphi 2 \\ \alpha 3 & \beta 3 & \gamma 3 & \varphi 3 \\ \alpha 4 & \beta 4 & \gamma 4 & \varphi 4 \end{bmatrix} \tag{1}$$

A Performance Matrix

Here α = ND, β = TC, γ = PC and φ = NS

The performance matrix shows possible values of network parameters for a particular traffic congestion zone.

Eigen values can be calculated by using the following expression

$$\left|\Delta - \lambda I\right| = 0 \tag{2}$$

The Eigen values or characteristic roots (λs) represent the performance of various network parameters (ND, PC, NS and TC. The priority of network parameters, which are being considered, is represented in the terms of weights. And using these performance parameters and weights we determine the cost function of each node. Hence, cost function can be calculated using equation (3),

$$\textbf{Cost function } \text{``}F(c)\text{''} = W_1\lambda_1 + W_2\lambda_2 + W_3\lambda_3 + W_4\lambda_4 \tag{3}$$

Here W_1, W_2, W_3 and W_4 are the assumed weights, whose values may vary from 0 to 1. $\lambda 1$, $\lambda 2$, $\lambda 3$ and $\lambda 4$ represent performance of parameters calculated in equation 2. The values of network parameters (ND, TC, NS and PC) are taken from four different congestion zones and ranked using AHP modeling depicted in Table1.

Table I: AHP modeling of network parameters (ND, TC, NS and PC)

Maximum traffic congestion (Max. Min.)	**Moderate traffic congestion (Max. Min.)**	**Minimum traffic congestion (Max. Min.)**	**No (open) traffic congestion (Max. Min.)**
8 to 7	6 to 5	4 to 3	2 to 1

The power consumed is proportional to the network traffic congestion and hence, the cost of each node. The optimal path is determined by minimizing the total cost of each route by finding the minimum cost function (Fmin) using following equation

$$\mathbf{Fmin} = \sum_{i=1}^{4} Wi\lambda i \times n \tag{4}$$

Where, n is the number of nodes on the selected path. For example, the performance matrix in equation 5 of a node shows the network parameters taken at maximum traffic congestion. Node density has been assumed to be constant, by ranking it to the highest. Similarly, node status is also ranked highest, assuming that all nodes are active in likely-hood of communicating node.

$$\Delta = \begin{bmatrix} 8 & 5 & 4.9 & 8 \\ 8 & 5.2 & 5.1 & 8 \\ 8 & 5.4 & 5.11 & 8 \\ 8 & 5.4 & 5.0 & 8 \end{bmatrix} \tag{5}$$

A Performance Matrix

Solving the performance matrix yields the values of λ_1, λ_2, λ_3 and λ_4 to be equal to 26.1912, 0, 0.0101, and 0.1087,respectively and then the cost function is calculated using equation1, as C1 = 26.31. In order to ensure equal priority to all network parameters, equal weightage is given to the weights, i.e. $W_1 = W_2 = W_3 = W_4 = 1$. Hence, the cost functions for the remaining nodes, for same traffic congestion zone, are calculated using the same procedure. For each of the possible paths, the minimum cost (Fmin) is calculated using equation 4. Similarly, the cost function can also be determined at moderate, minimum and no (open) congestion .The path which has lowest cost function is considered as the optimal path. The complete process involving the determination of the optimal path is depicted using the flow chart as shown in Figure1.

Now the total energy consumed for the routing path can be calculated using,

$$E_T = \sum E_t + \sum E_r + \sum E_{int} \tag{6}$$

Where, E_t = Transmit mode energy on each node along the route
E_r = Receive mode energy on each node along the route
E_{int} = Initial energy on each node along the route in ideal mode
Once we know the consumed energy along path, then the energy saved can be calculated.

3. SIMULATION RESULTS AND DISCUSSION

3.1 Simulation Environment

OPERA has been implemented on MATLAB -TOOL. At the initial state of simulation, 32 wireless nodes are placed on a square field of 1500m × 1500m. Here, each connection has been specified as a randomly chosen source-destination pair. The packet sizes are fixed to maximum, moderate, minimum and open number of bytes. Every node has some initial cost which depends on the different traffic congestion zones. Further, this node cost is used to represent the initial traffic load. Moreover, we have performed simulation with variable number of nodes.

3.2 Comparison with Existing Routing Algorithms

To get a better idea of the performance of OPERA, it has been compared with AODV using the QualNet (5.0.2) simulator using genetic, energy model with supply voltage of 6.5V.The simulation analysis performance parameters being used shown in Table: 2.

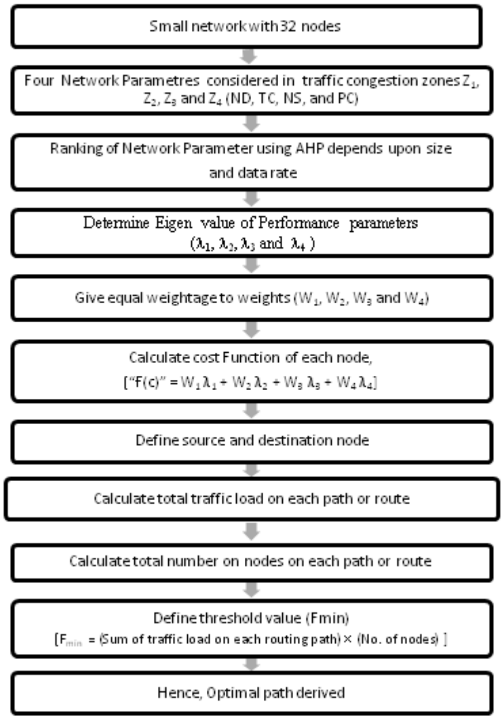

Figure 1: Flow chart of OPERA

Table II: Simulation Parameters for Energy Based Performance Analysis

Simulator Parameters		**Scenario Parameters**	
Mac Type	IEEE802.11	Area	1500 × 1500
Protocol	AODV	Simulation Time	240sec.
Network	Static	Battery Model	Linear
Traffic Data Rate	Variable bit rate (512,256,128,64)	No. of Nodes	10,20,32
Antenna	Omni -Directional	Node Status	Active
Channel Freq.	2.4 GHz	Network Model	Random(OPERA)

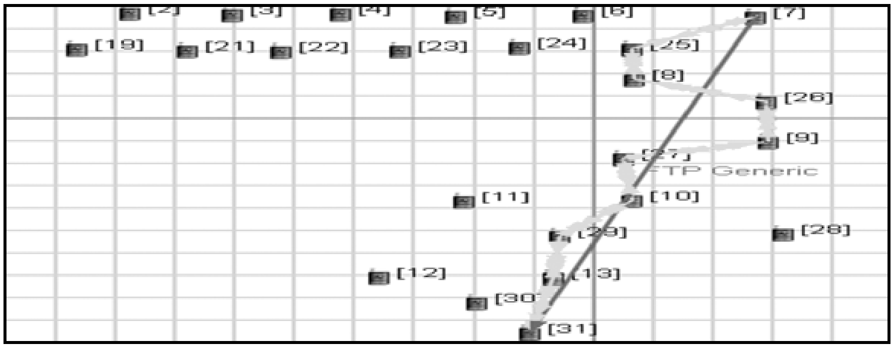

Figure 2: AODV routing path

3.3 Varying Node Density

The set of experiment networks (Fig 2 & 3) studies the impact on average route cost, number of hops taken and average energy consumed by OPERA and AODV protocol by varying the number of nodes. We have considered a maximum of 32 nodes, all being active. We have performed the

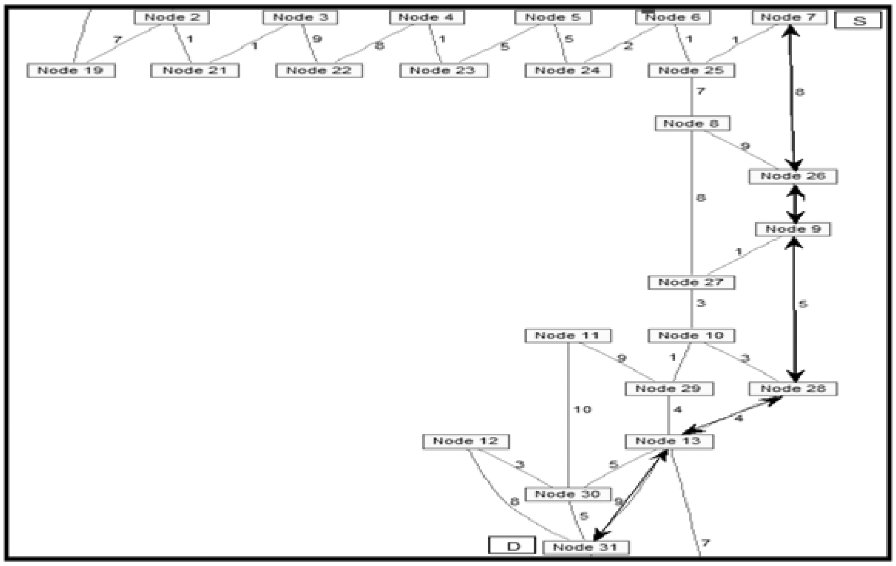

Figure 3: OPERA routing path

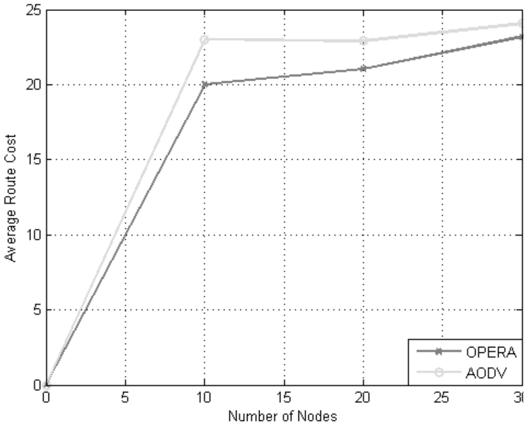

Figure 4: Average Cost V/s Number of Nodes

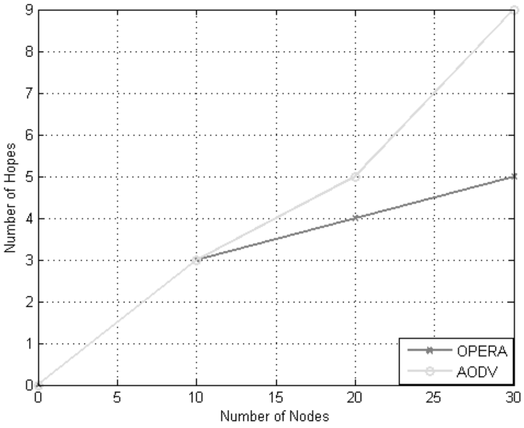

Figure 5: Number of Hopes V/s Number of Nodes

simulation by taking 10, 20 and 32 nodes.

Figure 4 depicts that the average cost of routes is lesser in OPERA as compared to AODV Protocol. Generally, route cost represents power consumption. Hence OPERA out-performs AODV.

Figure 5 depicts that as the number of nodes increases, there is an increase in number of hopes. But in OPERA, average number of hopes is lesser as compared to AODV. Here, maximum number of hopes implies maximum energy consumption.

In figure 6, 7, 8 and 9, we have varied the traffic congestion at maximum, moderate, minimum and open data bytes, so as to analyze the impact of the variation on the total energy consumed. Comparatively, OPERA consumes lesser energy than AODV. Through mathematical analysis , we observe that the average energy saved is about 8.29% per hour at maximum bit rate ,7.60% per hour at moderate bit rate, 7.30% per hour at minimum bit rate and 7.00% per hour at very low or open bit rate.

The results are tabulated in tables 3, 4 and 5. Therefore, it is observed OPERA has lesser

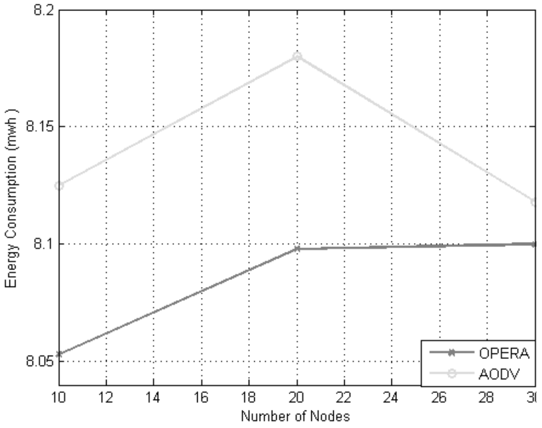

Figure 6: Energy Consumption V/s Number of Nodes (At Maximum Traffic)

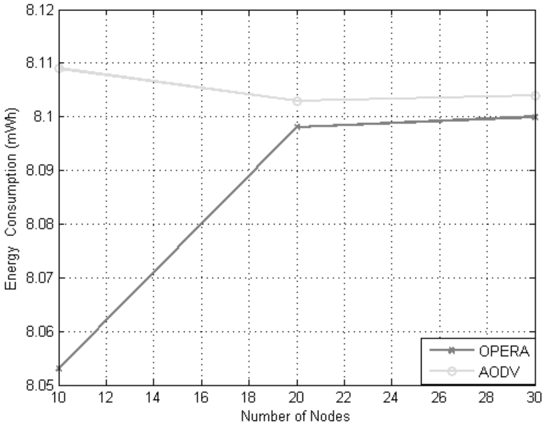

Figure 7: Energy Consumption V/s Number of Nodes (At Moderate Traffic)

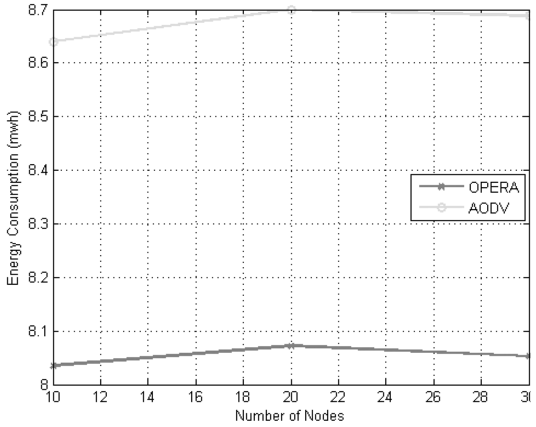

Figure 8: Energy Consumption V/s Number of Nodes (At Minimum Traffic)

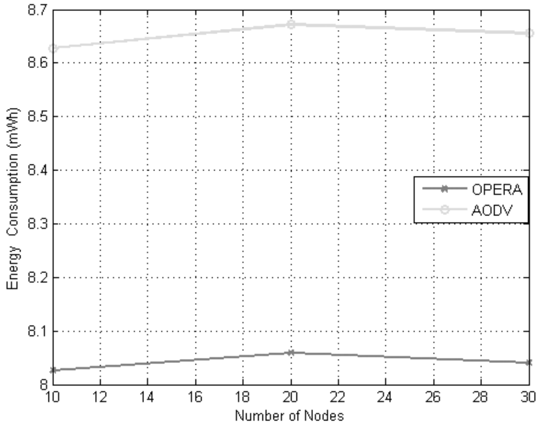

Figure 9: Energy Consumption V/s Number of Nodes (At Open Traffic)

Table III: OPERA simulation results

S	D	Path	Item		E_T at Max T_c (mWh)	E_T at Mod T_c (mWh)	E_T at Min T_c (mWh)	E_T at Open T_c (mWh)
			No. of hopes	ARC				
1	8	1,3,5,6,8	4	27.5	8.005	8.053	8.035	8.030
3	8	3,5,6,8	3	27.81	8.001	8.040	8.027	8.026
7	31	7,26,9,28,13,31	5	23.71	8.060	8.098	8.072	8.059
9	31	9,28,13,31	3	23.50	8.009	8.040	8.053	8.040

average power consumption as compared to AODV.

4. CONCLUSION

In the wide-spreading field of wireless ad hoc networks, power efficient routing is of prime importance. Hence, in order to achieve this goal, we have proposed a novel adaptive optimized power efficient routing algorithm (OPERA). Known technique like AHP has been used in the OPERA

Table IV: AODV simulation results

S	D	Path	Item		E_T at Max T_c (mWh)	E_T at Mod T_c (mWh)	E_T at Min T_c (mWh)	E_T at Open T_c (mWh)
			No. of hopes	ARC				
1	8	1, 3, 5, 7, 9, 8	5	28	8.725	8.719	8.665	8.634
3	8	3, 4, 6, 8	3	28.87	8.720	8.704	8.640	8.628
7	31	7, 25, 8, 26, 9, 27, 10, 29, 13, 31	9	25.12	8.780	8.733	8.700	8.672
9	31	9, 27, 10, 29, 13, 31	5	23.68	8.750	8.725	8.688	8.655

Table V: Energy saved (E_s) in OPERA as compared to AODV

E_s At Max T_c	E_s At Mod T_c	E_s At Min T_c	E_s At open T_c
8.29%	7.60%	7.30%	7.00%

algorithm, by use of four key network parameters (ND, NS, TC and PC), whose values are determined in accordance with different congestion zones. It has been shown that that OPERA is on an average 7.5% more power efficient as compared to AODV.

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