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Energy-efficient AODV using Super-increasing knapsack

Mohamed A. Ryan*, Sayed Nouh, Aly M. El-Semary

Systems and Computer Engineering Department, Faculty of Engineering, Al-Azhar University, Cairo, Egypt

***Correspondence:** Eng_ryan2016@outlook.com

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ABSTRACT

Abstract – Mobile Ad Hoc Network (MANET) consists of wireless mobile nodes in a self-organized environment devoid of fixed infrastructure and centralized management. The mobility of nodes leads to rapid and unpredictable changes in network topology. Such environment increases link failures and consequently increases the power consumption of the participating nodes. Using unaware-energy routing protocol shortens the network lifetime. Therefore, this paper is devoted to introducing an Energy Efficient Ad hoc on Demand Distance Vector (EEAODV) routing protocol to prolong the network lifetime. Specifically, the proposed protocol utilizes the super-increasing knapsack to select the best energy-efficient path between the source and destination. The suggested scheme has been implemented using the network simulator NS2 Version 2.31. The proposed EEAODV protocol is compared with the standard Ad hoc On-Demand Distance Vector (AODV) and Energy Distance Aware Ad hoc On-Demand Distance Vector (EDA-AODV) schemes. The experimental results in terms of throughput and the number of alive nodes under various scenarios show that the proposed protocol outperforms the other two protocols.

KEYWORDS: AODV, EEAODV, Energy efficient, Super-Increasing knapsack.

بروتوكول توجيه AODV كفء في استخدام الطاقة باستخدام حقيبة فائقة التزايد

محمد أحمد ريان*، سيد نوح، علي محمد السمري

قسم هندسة النظم والحاسبات، كلية الهندسة، جامعة الأزهر، مدينة نصر، 11884، القاهرة، مصر

***البريد الالكتروني للباحث الرنيسي :** Eng_ryan2016@outlook.com

الملخص

الشبكات المتنقلة التي تستخدم لاغراض معينة هي شبكات تتكون من مجموعة من العقد اللاسليكة المتنقلة، وتعمل هذه الشبكات في بيئة ذاتية التنظيم وخالية تماماً من أي بنية تحتية ثابتة او إدارة مركزية. تؤدي حركة العقد إلى تغييرات سريعة وغير متوقعة في طوبولوجيا الشبكة مما يؤدي الي زيادة فشل الترابط بين العقد وبعضها ويتسبب هذا في تكرار إعادة إكتشاف المسارات بين العقد، والذي يؤدي بدوره الي زيادة استهلاك طاقة العقد المشاركة. استخدام بروتوكول توجية غير مدرك لطاقة العقد المشاركة يؤدي الي تقصير عمر الشبكة. لذلك، تم تخصيص هذه الورقة لتقديم بروتوكول توجيه مخصص موفر للطاقة (EEAODV) لإطالة عمر الشبكة. وعلى وجه التحديد، يستخدم البروتوكول المقترح الحقيبة فائقة التزايد لتحديد أفضل مسار موفر للطاقة بين

المصدر والوجهة. تم تنفيذ المخطط المقترح باستخدام محاكي الشبكة NS2 الإصدار رقم 2.31. تمت مقارنة البروتوكول المقترح (EEAODV) مع المخططات القياسية المخصصة لمتجه المسافة حسب الطلب (AODV) ومخططات قياس مسافة الطاقة المخصصة حسب الطلب (EDA-AODV). أظهرت النتائج التجريبية من حيث الإنتاجية وعدد العقد الحية في ظل سيناريوهات مختلفة أن البروتوكول المقترح يتفوق على البروتوكولين الآخرين.

1. INTRODUCTION

Wireless networks are comprised of a collection of mobile nodes that utilize radio waves as a means of communication to exchange data with each other. These networks enable users to seamlessly link diverse nodes without the need to buy, install, or connect cables [1]. Consequently, wireless networks offer valuable functionalities such as mobility and the reduction of both installation time and cost. Broadly, infrastructure networks and infrastructure-less networks are considered the two main types of wireless networks [2].

Infrastructure networks refer to centralized networks that employ a central point called base station to control the communication between the participating devices. The base station represents the backbone of the infrastructure networks where all communications are relayed through it. specifically, any node needs to launch a communication with another node, it has to establish a connection with the base station first, even if the origin and target nodes are immediate neighbors [3].

On the contrary, infrastructure-less networks do not have any centralized points. Hence, nodes work in self-organized manner, each node works as an end point and also as a router at the same time.

MANET is the most prominent type of infrastructure-less networks. Where nodes in MANET are distributed in an arbitrary manner and all communications between the participating nodes are taking place in a multi-hop fashion. That means, packets are forwarded from one node to another through the path from the source node to the destination. The easy installation nature of MANET makes it appropriate for application in various fields, including military operations, disaster areas, and personal area networks [4].

In the realm of MANET, nodes exhibit unrestricted mobility, leading to swift and unpredictable alterations in network topology. Consequently, the connections between nodes often experience frequent disruptions. Also, the energy limitations imposed on the nodes result in a diminished packet delivery ratio to the destination. Providing energy-efficient routing protocol in such environment is a challenge [2].

In general, the responsibility of directing packets from a node to another towards a target node, falls under the purview of the routing protocol. Routing protocols in MANETs can be broadly classified into three primary categories based on how mobile nodes acquire and sustain routing information [5] as shown in figure 1.

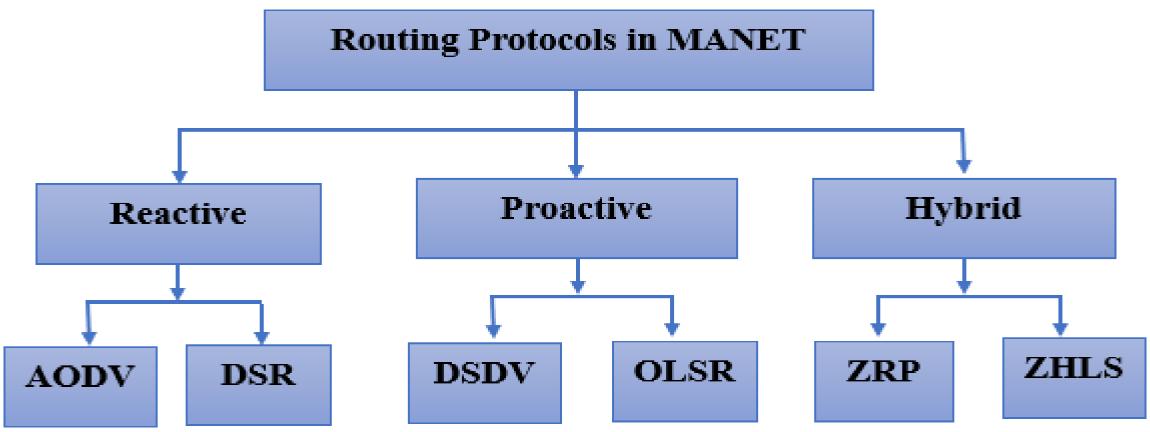

Figure 1: Well-known MANET Routing Protocols

Routing protocols that are reactive or on-demand are efficient in terms of bandwidth utilization. In the context of reactive routing strategies, to preserve the battery lifetime and to also reduce routing overhead the nodes establish and retain routes solely to nodes that engaged in active communication with them. In reactive routing protocols, the route between the source and destination is established only when the source node needs to communicate with the destination and there is no valid route to that destination in its routing table. AODV is one of the widely used reactive routing protocols [6].

In proactive or table-driven routing protocols, the routes between the participating nodes are predefined. Nodes periodically send routing packets to each other to exchange their routing information, that resulting in, every node maintains an up-to-date view of the whole network. When any topology change is occurred, routing packets are propagated to inform the nodes regarding this change, consequently the nodes update their routing information. “Destination-Sequenced Distance Vector Routing” (DSDV), “Optimized Link State Routing” (OLSR) and “Fisheye State Routing” (FSR) are examples of table-driven routing protocols. The main issue in proactive is the overhead that is caused by the periodic sending of routing packets [7].

The hybrid routing protocols are implemented in a way that combine the benefits of proactive along with the benefits of reactive schemes. “Zone Routing Protocol” ZRP is an example of the hybrid routing protocols [8].

The rest of the article is structured as following: Section 1.1 explains the standard AODV. The related works are discussed in section 2. The proposed scheme EEAODV is presented in section 3. Section 4 shows simulation parameters, scenarios and results. Finally, section 5 provides the conclusion.

1.1. AODV OVERVIEW

AODV is considered as one of the reactive well-known routing schemes. In the AODV, routes are only discovered when they are required and intended to be used [9]. In other words, if a source node wants to communicate with a target node and there is no pre-existing path in its routing table to the destination, the originating node initiates the path discovery process [10]. To discover a path in AODV protocol, the origin node creates a Route Request (RREQ) packet and broadcasts it to its neighboring nodes. Upon receiving the RREQ packet, a neighboring node updates its routing table by creating a reverse route to the origin node. The neighbor node could be either the target node or an intermediate node. In case, it is the target node, it initiates a process known as the Route Reply process. This involves generating a Route Reply (RREP) packet and transmitting it to the origin node through the established reverse path [11]. Alternatively, if the neighbor node is not the destination, it searches in its routing table for a valid path to that required destination. If there is a fresh enough path to the destination, the neighbor node will start the route reply procedure by sending a RREP packet through the established reverse path to the originating node. If the transit node does not find a fresh enough path in its routing table to the target, it will continue the route discovery procedure by broadcasting the route request packet to all of its neighboring nodes. This procedure will be repeated at every intermediate node that participates in the route discovery procedure until the route request packet arrives at the final destination or to a transit node that has a fresh enough path to the final destination node. In the other direction, when a node receives a RREP packet, it establishes a route to the originator of the RREP. If the node is not the source node, it will unicast the RREP to the source node through the established reverse path. If the node is the source node itself, it will start sending the data packets to the final destination through the established forwarding path. In case the source node later receives another RREP packet with a higher sequence number or with the same sequence number but with a lower hop count, the source node will update its routing table with this better path and use that path to keep forwarding the data to the destination [12].

For clarity, Figure 2 is included to illustrate the route discovery and route reply procedures in the AODV protocol. In the figure, the source node is represented as S while the destination node is represented as D. Node S needs to communicate with node D but there is no valid path in the routing information of node S to that destination. Consequently, node S will initiate the path discovery process by flooding a RREQ packet to its neighboring nodes which are A, B, and N. In this scenario the neighboring nodes do not know the route to the destination as well, so they will build reverse routes to S then they will broadcast the RREQ to their neighboring nodes. The process will be repeated until the RREQ packet arrives at node D. For example, node Y will receive the RREQ packet from node A, while node X will receive RREQ packets from nodes B and N. In this case, node X will accept the first received RREQ and discard the other. Node Y and X will broadcast the RREQ packet. In this scenario, node D will receive the first RREQ from node Y while node Z will receive the RREQ from node X. Accordingly, node D will immediately start the route reply procedure by forwarding a RREP packet to node S through the established reverse path Y, A, and S. Later, node D will discard the RREQ that was sent from node Z, as node D previously had received the same RREQ from node Y. Upon receiving the RREP, nodes Y, A, and S will store the forward path to the destination node D. Finally, node S will start sending the data packets to the destination via the forward path A, Y, and D.

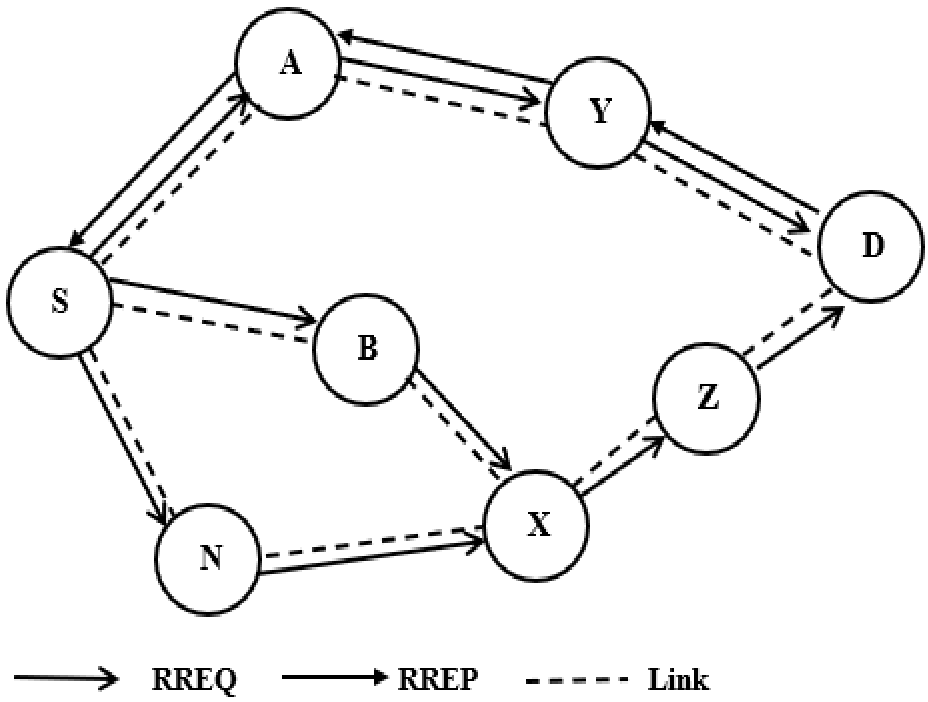

Figure 2: AODV Routing Mechanism.

2. RELATED WORKS

In [13], the authors proposed Gradient Boosted Energy Optimization Model (GBEOM) scheme that uses Weighted Multi-objective Cluster-based (WMC) algorithm to perform energy-efficient routing protocol in MANET. GBEOM divides the network into clusters, to achieve efficient clustering procedure, the proposed scheme measures the bandwidth and residual energy for each node in the network. Accordingly, it assigns a weight for each node based on the measured value. Then, the nodes that have similar weight values are grouped into clusters. To reduce the energy consumption of the network, the proposed scheme elects the higher weighted node in each cluster as a cluster head, that node will be responsible for transmitting the data packets to the destination.

The researchers in [14] proposed an optimized routing scheme Ad hoc On-demand Multipath Distance Vector Sleep Scheduling Particle Swarm Optimization (AOMDV-SSPSO) to reduce the energy consumption in MANET by using scheduling sleep technique. The proposed scheme works in three primary phases which are path setup, ideal path selection and sleep scheduling technique. In path setup phase, multiple routes are established from the source to the destination. While the optimal path from the source to the destination is selected in the ideal path selection phase. The sleep scheduling techniques puts the nodes in sleep mode when they are not in use and their inactivity does not cause a local partition in their immediate region.

In [15], the researchers introduced the scheme Dynamic Source Routing Fruit Fly Algorithm (DSR-FFA) to create multiple paths between the source and destination to balance the data transmission process and reduce the energy consumption. Fruit Fly Algorithm (FFA) is used to find the fitness value for each available path based on energy factor. these fitness values are stored in the most efficient order to be used in the data forwarding process. the suggested scheme was implemented using NS2. The experimental results indicate that DSR-FFA saves 20% of the energy consumption compared with the existing ACO scheme.

The researchers in [2] introduced EDA-AODV routing scheme to reduce the overhead and energy consumption in the network. The route between the source and destination is selected based on two metrics which are the node residual energy and the distance between each node in the route and its previous hop. EDA-AODV modified the RREQ packet of the standard AODV to carry the coordinates and the residual energy factor REF of the transmitting node. When a neighboring node gets a RREQ packet, it uses the included coordinates to calculates the distance to the previous hop. If the distance is in range from 50% to 70% of the transmission range, the node will calculate its residual energy and compares the it with the REF included in the received RREQ packet. The node will update the coordinates of RREQ packet with its own coordinate and will update the RE only if its residual energy is less then RE included in the received RREQ. This process will be repeated along the path to the destination. The RREQ will reach the destination node with lowest RE. When the destination node receives the first RREQ, it starts a timer and waits to collect multiple paths to the source node then apply the max mini technique to select the route with the best residual energy to the source node.

In [16], the authors introduced an improved form of AODV called Intelligent Routing AODV (IRAODV) to enhance the energy consumption in MANET. The proposed scheme uses the strength of the received signal to calculates the distance between nodes to find out which nodes located within the same region. The scheme then elects one node to transmit all data packets while deactivates the transmission of other nodes. The proposed scheme implemented using the network simulator NS2. The results show that IRAODV has 50% PDR and 25% throughput higher than the standard AODV. IRAODV also provides 65% less power consumption than AODV.

The researchers in [17] proposed the scheme Energy Efficient Routing EER to reduce the link failure and enhance the network performance. The proposed scheme prevents low-battery nodes to participate in the route discovery scheme to guarantee that the route from source to destination is energy-efficient route. Excluding the low-battery nodes would decreases the performance of the network when all the neighboring nodes are low-battery.

3. PROPOSED EEAODV

In the standard AODV, the route between the source and destination is selected based on the two metrics, hop count and sequence number. AODV does not consider the energy level of the participating nodes along the route from the source to the destination. That would lead to more over load on low battery nodes, this leads to more link failure that results in repeating the route discovery process and broadcasting the route request which increases the power consumption and shortens the lifetime of the whole network.

The energy efficient proposed scheme EEAODV overcomes this shortcoming to enhances the performance of the standard AODV. The proposed protocol utilizes the super-increasing knapsack to calculate energy weights for different paths between a source and destination to select the energy efficient route to the destination. The rest of this section discusses the details of the proposed protocol. Specifically, section 3.1 introduces super-increasing knapsack. Updating the energy parameters of the participating nodes between source and destination is discussed in section 3.2. Section 3.3 provides the details of calculating the energy weights of the routes between source and destination. Finally, 3.4 presents examples to illustrates the proposed protocol.

3.1. Super-increasing Knapsack

A super-increasing Knapsack is a special type of sequence in mathematics where each term is greater than the sum of all the preceding terms [18]. In other words, a sequence {a1, a2, a3, ..., an} is considered super-increasing if Equation 1 is achieved for every i from 2 to n, the following inequality holds:

$$a_i > \sum_{j=1}^{i-1} a_j \qquad (1)$$

In simpler terms, each term in the sequence is strictly larger than the sum of all the terms that come before it. Example, the sequence {1, 2, 4, 8, 16} is considered as super-increasing knapsack because the value of each term is greater than the sum of the preceding terms e.g. the value of the fourth term is greater than the sum of the first three terms (i.e. 8 > 1+2+4).

3.2. Updating the Energy Parameters

The proposed protocol EEAODV follows the standard technique of AODV protocol with introducing energy parameters to the RREQ and RREP packets. The proposed scheme categorizes the participating nodes according to their residual energy. Specifically, the protocol classifies the nodes into four energy levels E_1, E_2, E_3 and E_4 that are less than or equal to 25%, 50%, 75% and 100% of node residual energy, respectively as in Table 1.

Table 1: Energy Parameters and Conditions.

Parameters	Condition
E_1	Residual energy of node is <= 25%
E_2	Residual energy of node is > 25% and <=50%
E_3	Residual energy of node is > 50 % and <=75%
E_4	Residual energy of node is > 75%

Each node along the route between the source and destination updates the packet energy parameters either in RREQ or RREP packets according to the flow chart described in Figure 3. When a node n_j is a source or a destination it initiates the four energy parameters E_1 to E_4 along with the hop count h to be equal to zero. On the other hand, if the node n_j is an intermediate node, it extracts these parameters from the received packet and increments the hop count. In both cases, the node uses its residual and initial energies to update the energy parameters based on its current energy level that is calculated using Equation 2.

$$E_L^j = \left\lceil \frac{100\ (E_c^j / E_i^j)}{25} \right\rceil \qquad (2)$$

Where E_L^j is the energy level of node j, E_c^j is the current or residual energy of node j and E_i^j is the initial energy of node j. The equation is multiplied by 100 and divided by 25 to map the energy level from 1 to 4. In addition, the symbol $\lceil x \rceil$ refers to the ceiling of the value *X*. According to the node energy level the corresponding energy parameter will be updated by adding 2^h to satisfy super-increasing knapsack condition where the value of 2^h is greater than the sum of the values of 2^{h-1}, 2^{h-2}, 2^{h-3}, …, 2^0. For example, if the current level of the node *j* is the third level and the hop count is 4 then the parameter E_3 is updated as $E_3 = E_3 + 2^4$ while the other energy parameters will not be updated at that node. The cumulative energy parameter between the source and destination will be defined according to Equation 3.

$$E_L = \sum_{i=1}^{h} 2^i \qquad (3)$$

where E_L represents the energy parameter from E_1 to E_4.

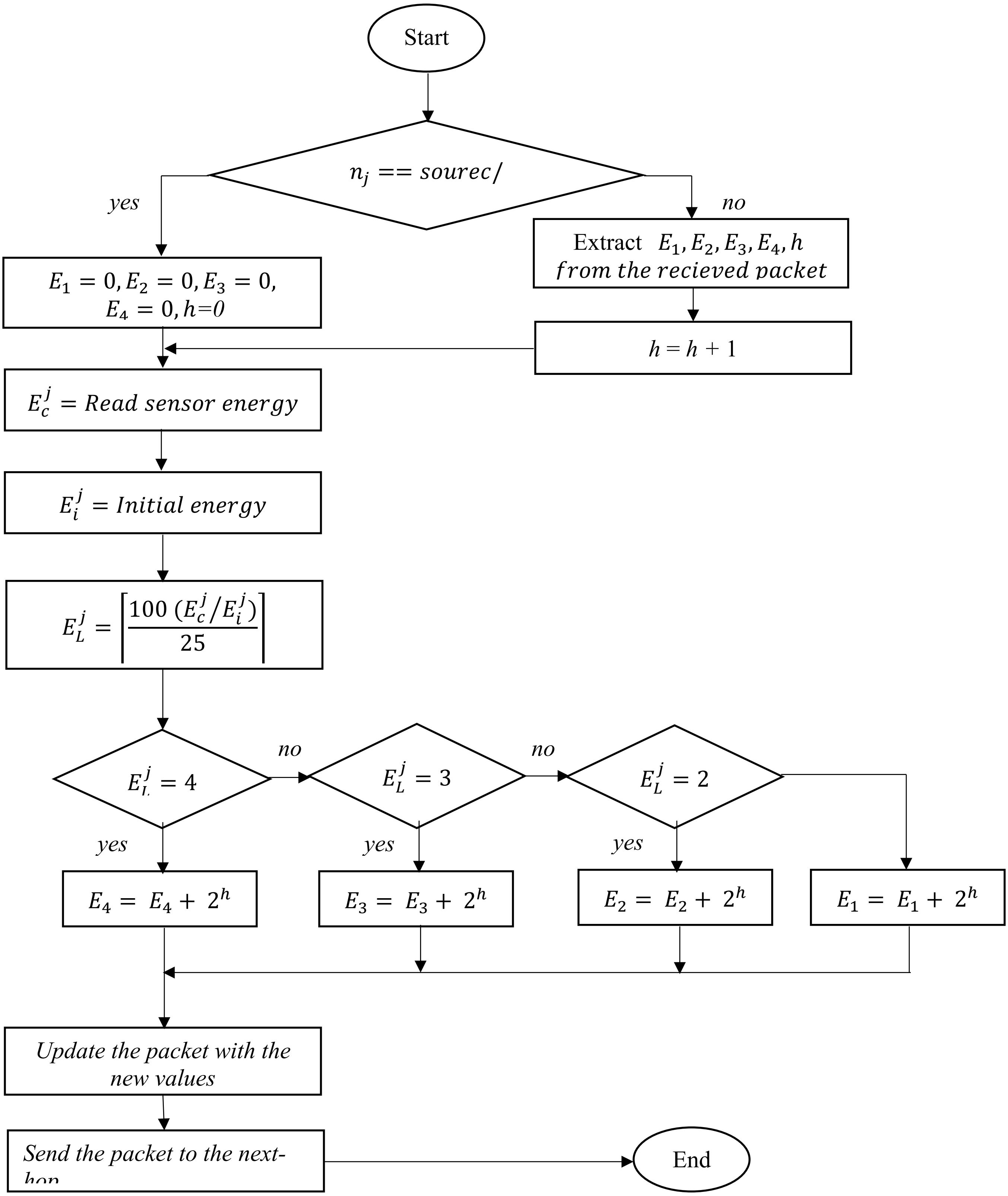

Figure 3: Flow Chart of update energy parameters in EEAODV

3.3. Calculating the Energy Weights

In this section the node calculates the energy weight for each path to decide the best efficient energy route. The node utilizes the accumulated energy parameters and hop count to calculate energy weight of each candidate path between source and destination as shown in flow chart of Figure 4.

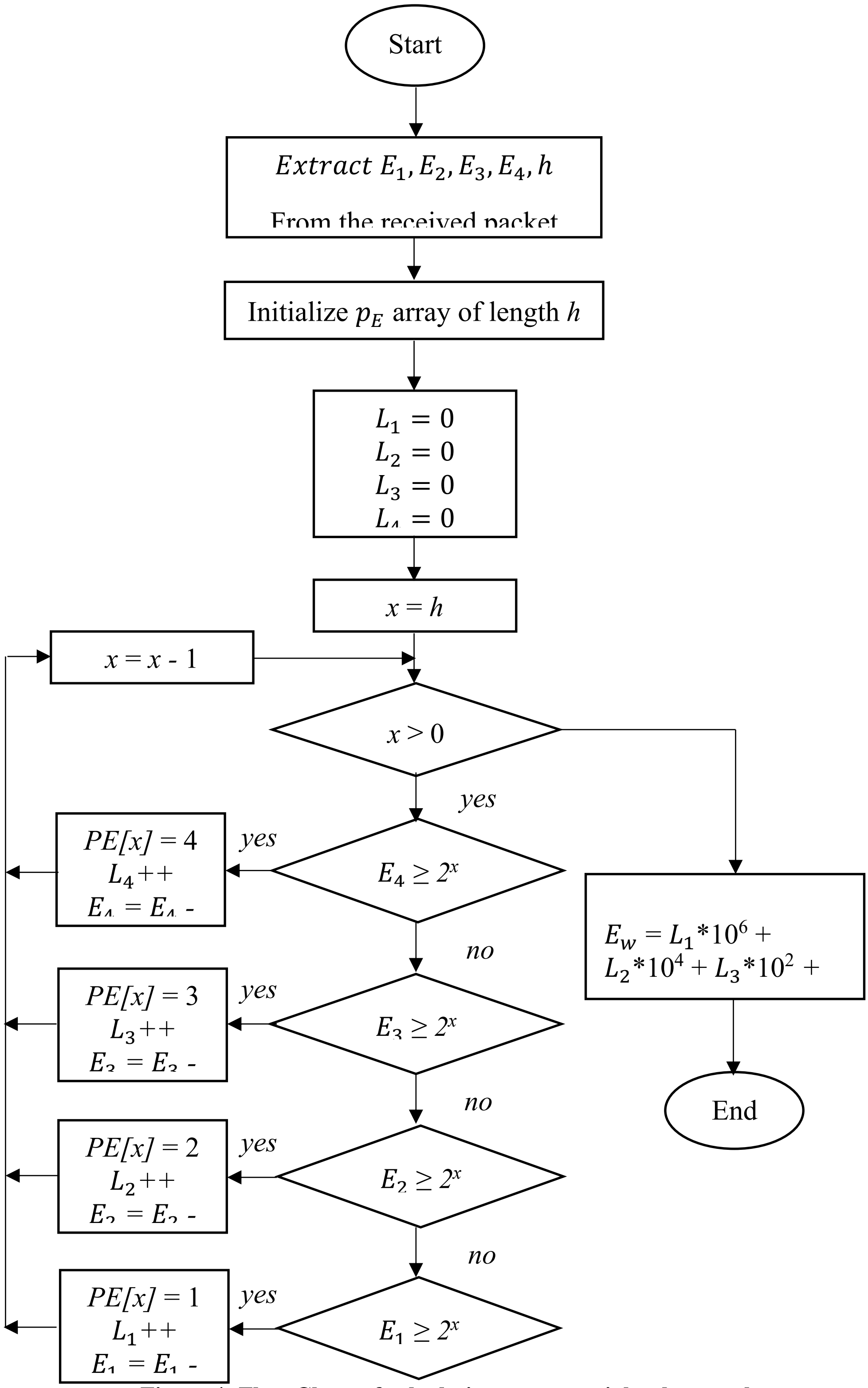

Figure 4: Flow Chart of calculating energy weight along path.

According to the flow chart in Figure 4, node *j* decides the best efficient energy route by extracting the four energy parameters E_1 to E_4 and hop count from the received packet then analyzing these parameters based on super-increasing knapsack. Specifically, the node *j* finds the number of nodes in each energy level along the path from the node *j* to a destination node according to Equations 4 and 6. And the variable x is initially set to be equal h.

$$L_i = \begin{cases} L_i + 1, & E_i \geq 2^h \\ L_i, & otherwise \end{cases} \quad (4)$$

$$E_i = \begin{cases} E_i - 2^h, & E_i \geq 2^h \\ E_i, & otherwise \end{cases} \quad (5)$$

$$x = x - 1 \quad (6)$$

Where L_i refers to the number of nodes belongs to level i where i = 1, 2, 3, and 4. And E_i represents the energy parameters of level i.

According to Equations 4 and 5, the node *j* at hop count h will check the four energy parameters of a candidate route, if the value of any energy parameter is greater than or equal to 2^h, the energy parameter will be decreased by the value of 2^h and the corresponding number of nodes of this energy level will be incremented by 1. For example, if energy parameter E_2 at hop count 6 is greater than 2^6 then E_2 will be decreased by 2^6 and the number of nodes at level 2 L_2 will be incremented by 1, then the value of x will be decremented as in Equation 6 to repeat the process at x=5. Also, the flow chart in Figure 4 preserves the energy level of each node at each specific hop count in the array PE that can help to visualize the energy status of all nodes along the path.

After calculating the number of nodes of each of the four levels L_1, L_2, L_3, and L_4, the energy weight E_w of each candidate path is calculated according to Equation 7.

$$E_w = L_1 * 10^6 + L_2 * 10^4 + L_3 * 10^2 + L_4 \quad (7)$$

Equation 7 is designed to give the boor energy route the highest weight, while the best energy route will have the lowest weight. The equation gives weights from *h* to $h*10^6$ to the candidate routes, where the route with the weight *h* is the best energy route while the route with the value $h*10^6$ is the worst. Therefore, the node will select the route with the minimum weight.

3.4. Examples of Calculating Route Energy Weight

In this section, two examples are presented to illustrate how the nodes calculate the weight of the candidate routes using the proposed scheme.

Figure 5 shows that the node *S* has a three candidate routes to the destination node *D*, it needs to decide which route is the best with respect to the energy and the hop count as well. Node S applies Equation 7, for the route with nodes number 7, 3, and 9 has energy weight

$E_w = 0 * 10^6 + 0 * 10^4 + 0*10^2 + 3 = 3$

While the weight of the route of nodes 4 and 6 has $E_w = 0 * 10^6 + 0 * 10^4 + 0*10^2 + 2 = 2$ and the weight of the third route with nodes 5,2, and 1 has $E_w = 0 * 10^6 + 0 * 10^4 + 0*10^2 + 3 = 3$, according to the proposed scheme, the best route is the route that has the smallest weight, so the node S will select the route of nodes 4 and 6. Not that the all nodes has energy level E4 but the selected route achieved the minimum hop count.

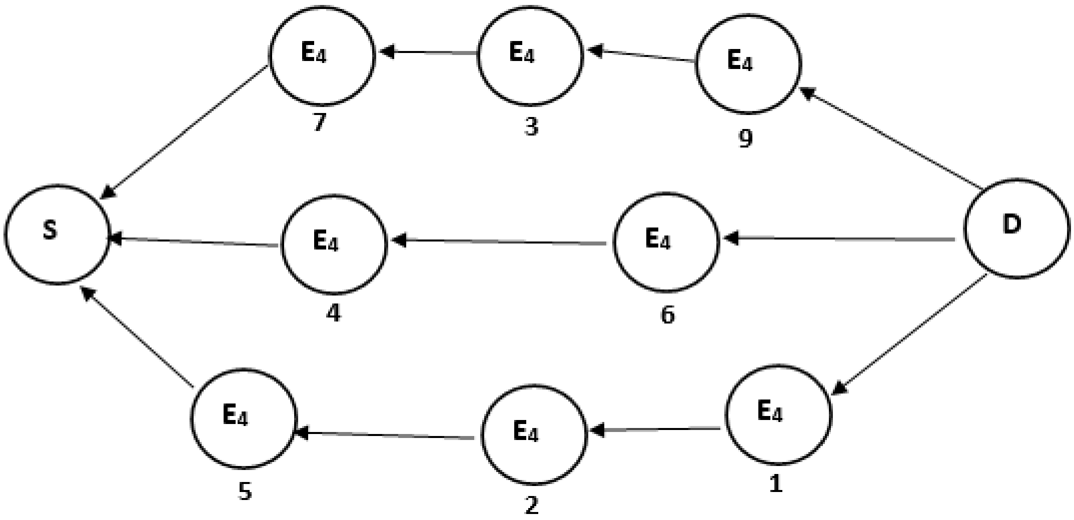

Figure 5: Route Energy Weight of EEAODV

Figure 6 represents the same topology as in Figure 5 but with different energy level for the participating nodes. The source node calculates the energy weights of the three candidate routes. The energy weight of the route with nodes 7, 3 and 9 is $E_w = 0 * 10^6 + 1 * 10^4 + 1*10^2 + 1 = 10101$ while the energy weight of route with nodes 4 and 6 is $E_w = 1 * 10^6 + 0 * 10^4 + 1 *10^2 + 0 = 1.0001*10^6$ and the energy weight of the third route with nodes 5, 2 and 1 is

$E_w = 1 * 106 + 1 * 104 + 0 *102 + 1 = 1.000101\times10^6$ so the node *S* will select the route of nodes number 7, 3 and 9 as the best route to the destination node *D*.

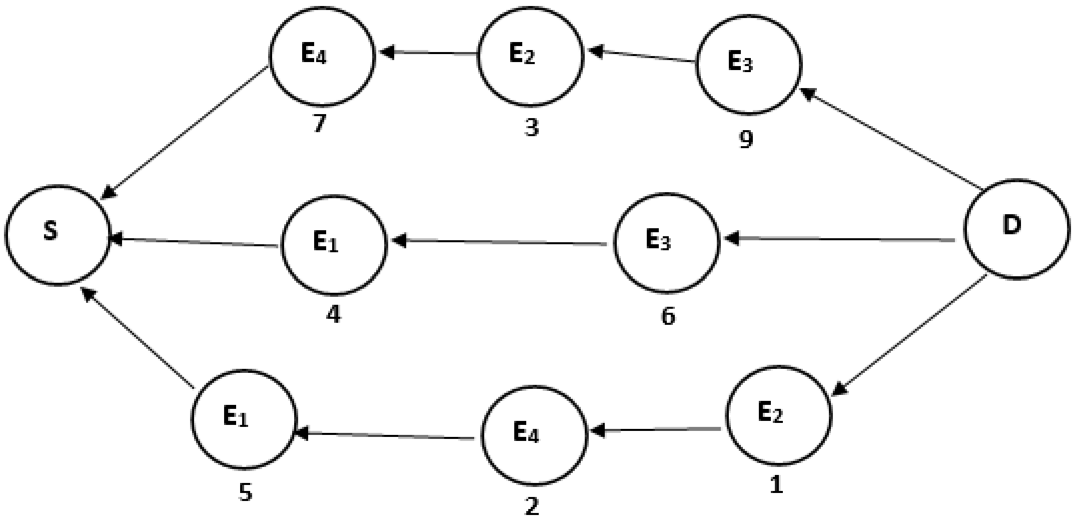

Figure 6: Route Energy Weight of Nodes with Different Energy Levels

4. SIMULATION RESULTS AND DISCUSSION

This section focuses on the performance assessment and comparative analysis between the proposed EEAODV, the existing scheme EDA-AODV and the conventional AODV in various scenarios. Evaluation is conducted based on metrics such as throughput and number of alive nodes.

Throughput refers to the actual amount of data transmitted and processed throughout the network. While the number of alive nodes indicates the current measurement of the overall nodes that still possess remaining energy and have not depleted it entirely [19].

Table 2: General Simulation Parameters

Simulation Parameters	Values	Simulation Parameters	Values
Network simulator	NS2 (version 2.31)	Number of nodes	50 – 90
Simulation area	800*400 m	maximum connections	25, 45
Mobility model	Random waypoint model	pause time	50-400 s
Simulation time	500 second	Mobility Speed	5 m/s -55 m/s
Routing protocols	EEAODV, AODV, EDA-AODV	Packet Size	512 b
Packets Rate	4 packet/second	Channel Type	Wireless
Antenna type	Antenna/Omni Antenna	Traffic Type	CBR
MAC Layer	802.11	Radio propagation model	Two ray ground
Initial energy of nodes	20 joules	Transmission energy (E_{tx})	0.6 joule
Reception energy (E_{rx})	0.3 joule	Interface queue length	50
Radio transmission range (R)	250 m		

4.1 Scenario 1

This particular scenario illustrates the impact of node mobility speed on the performance of the proposed scheme EEAODV, the standard AODV and the existing scheme EDA-AODV. The evaluation is conducted with reference to the parameters outlined in Table 3. In addition to the general parameters described in Table 2.

Table 3: Scenario 1 Parameters

Simulation Parameter	Value
Number of nodes	50
Mobility speed	5 - 55 m/sec
Pause time	5 sec
Number of sources	25

Throughput against Nodes mobility speed for EEAODV, EDA-AODV and AODV routing protocols is illustrated in the Figure 7. The results of the three protocols indicate that the higher the speed of nodes, the lower the throughput. For example, the throughput of AODV at the speed 5 m/s provides throughput of value 32000 bps while at speed 55 m/s the protocol provides throughput of value 27500 bps. This behavior is normal because a mobile node in the discovered path between the source and destination might goes outside the transition range of the adjacent forwarding nodes in the path. That leads to more frequent link failure that requires rediscovering the route. The route discovery process results in extra broadcasting which consumes the nodes energy. As a result, the life time of the network gets reduced which reduces the throughput. The results show that the proposed EEAODV scheme significantly outperforms both EDA-AODV and AODV. This is because the proposed scheme selects the route between the source and destination based on the global energy of the participating nodes which provides energy load balance and reduce the link failure.

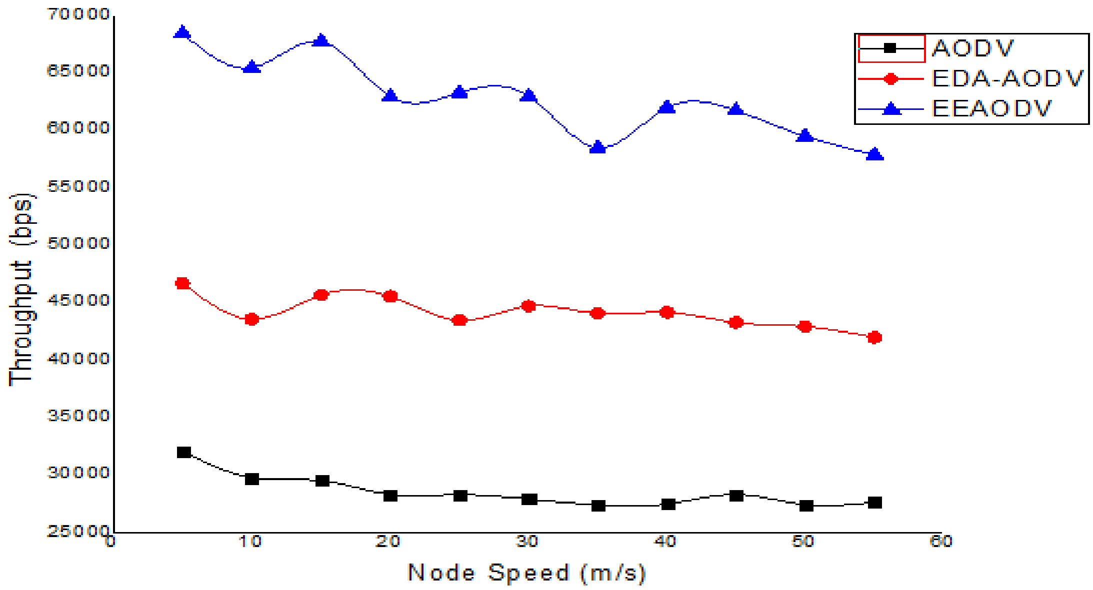

Figure 7: Throughput vs. Node Speed

Figure 8 illustrates Number of Alive Nodes vs Nodes Mobility Speed for EEAODV, EDA-AODV and AODV. The results indicate that for the three compared protocols the number of alive nodes decreases when the speed of nodes increases. For example, the number of alive nodes in EDA-AODV at the speed 5 m/s are 32 out of 50 nodes while at the speed 55 m/s the alive nodes are 27 nodes. This is because increasing the node speed in the network leads to more frequent link failure that requires rediscovering the route. Repeating the route discovery process results in more power consumption and hence a smaller number of alive nodes. The results represent that the proposed scheme outperforms both EDA-AODV and AODV. This is because the proposed scheme achieves energy load balance which prolongs the nodes life time.

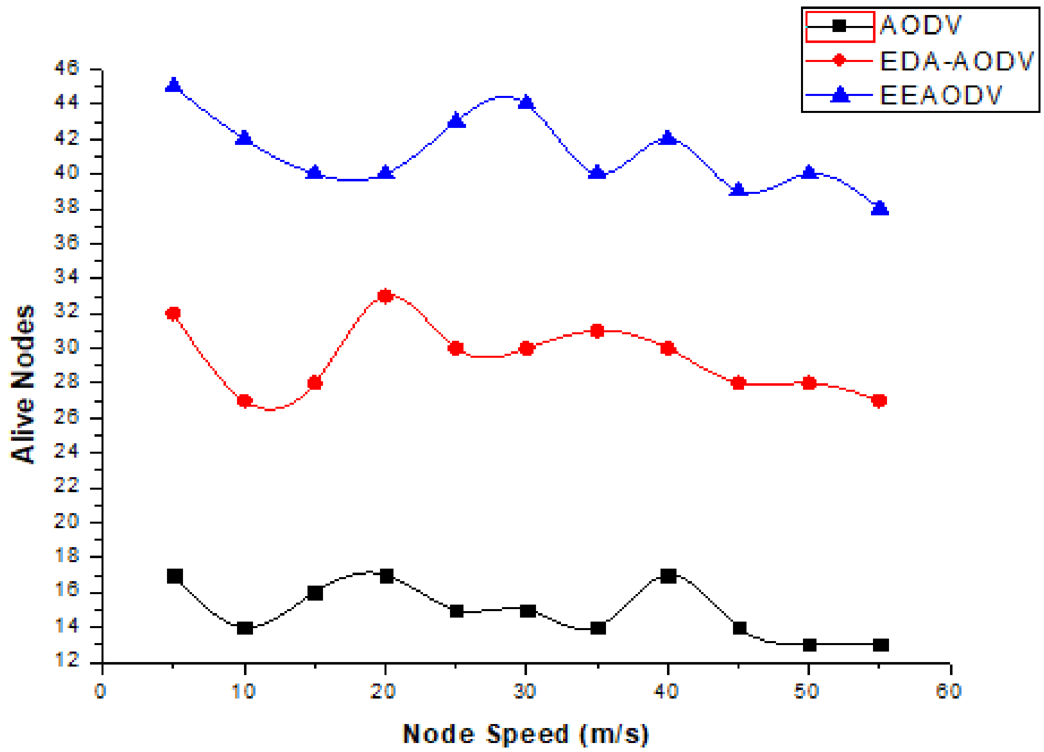

Figure 8: No. of Alive Nodes vs. Node Speed

4.2 Scenario 2:

In this scenario the influence of nodes pause time is measured for the three routing protocols EEAODV, EDA-AODV and AODV with respect to the throughput and number of alive nodes. The assessment utilizes the parameters outlined in Table 4, while maintaining the other parameters as indicated in Table 2.

Table 4: Scenario 2 Parameters

Simulation Parameter	Value
Number of nodes	50
Pause time	0 - 400 sec
Number of sources	25
Mobility speed	5 m/sec

Throughput vs pause time for the three compared routing protocol is illustrated in figure 9. It is evident that the increase in pause time leads to increase in throughput for the three protocols. For example, the proposed EEAODV at 0 second pause time provides throughput of 64000 bps while at 400 seconds pause time provides 69000 bps. This is attributed to the fact that an augmentation in pause time contributes to enhanced route stability. This behavior is normal because increasing the pause time means less in mobility and correspondingly less link failure between the participating nodes. The results show that the proposed scheme EEAODV outperforms both EDA-AODV and AODV, where EEAODV provides average 66300 bps while the EDA-AODV and AODV provides average throughput 45000 bps and 35000 bps respectively.

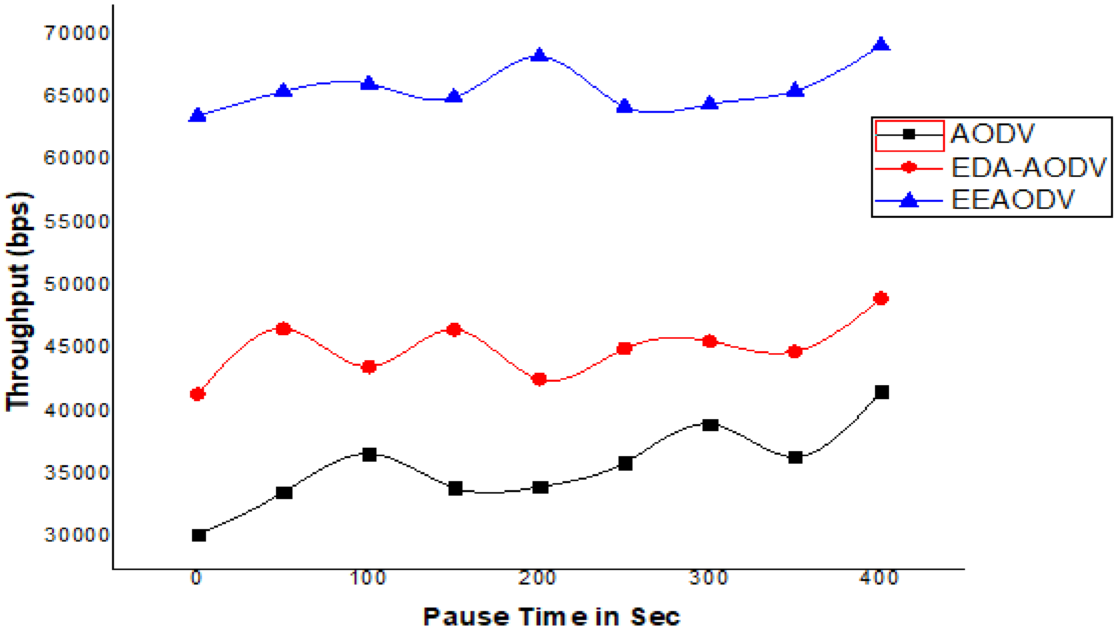

Figure 9: Throughput vs Pause Time

Figure 10 demonstrates the number of alive nodes against the pause time for EEAODV, EDA-AODV and AODV. The figure shows that the number of alive nodes for the three mentioned protocols increases when the pause time get increased. This is because increasing the pause time enhances the network stability thereby reduces the link failure. Reducing the link failure results in reducing the repeat of the route discovery process. Minimizing the rediscovery of the route between source and destination reduces the broadcasting which leads to reduced energy consumption and prolongs the network life time. The results indicate that the proposed scheme EEAODV outperforms both EDA-AODV and AODV where the average number of alive nodes in EEAODV (44 node) is significantly higher than the average number of alive nodes for EDA-AODV (25 node) and AODV (17 node). That is because EEAODV provide energy load balance by analyzing the energy status of all nodes that participate in the route, then selects the route that has highest efficient energy criteria.

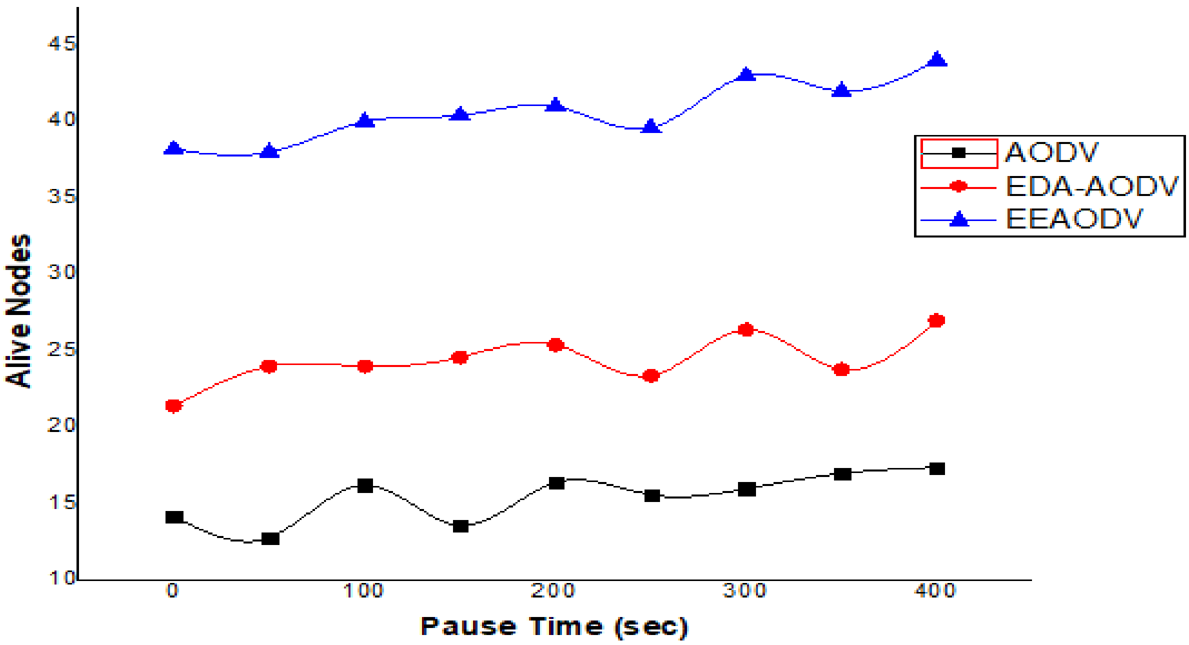

Figure 10: No. of Alive Nodes vs Pause Time

4.3 Scenario 3:

This scenario illustrates how number of nodes affects the performance of the proposed EEAODV and the existing scheme EDA-AODV and the standard AODV. The performance analysis is done with respect to the metrics throughput and number of alive. This scenario uses the parameters shown in table 5 along with the parameters mentioned in table 2.

Table 5: Scenario 3 Parameters

Simulation Parameter	Value
Number of nodes	50-90
Number of sources	45
Mobility speed	10 m/sec
Pause time	5 sec

Figure 11 depicts the throughput against number of nodes for the three protocols EEAODV, EDA-AODV and AODV. The figure shows that the network throughput diminishes as the number of nodes between the source and destination increases. This is due to increasing the number of nodes leads to increasing packet error probability also increasing the probability of link failure [20]. This leads to a reduction in network throughput. The results show that the proposed EEAODV outperforms both the existing scheme EDA-AODV and the standard AODV.

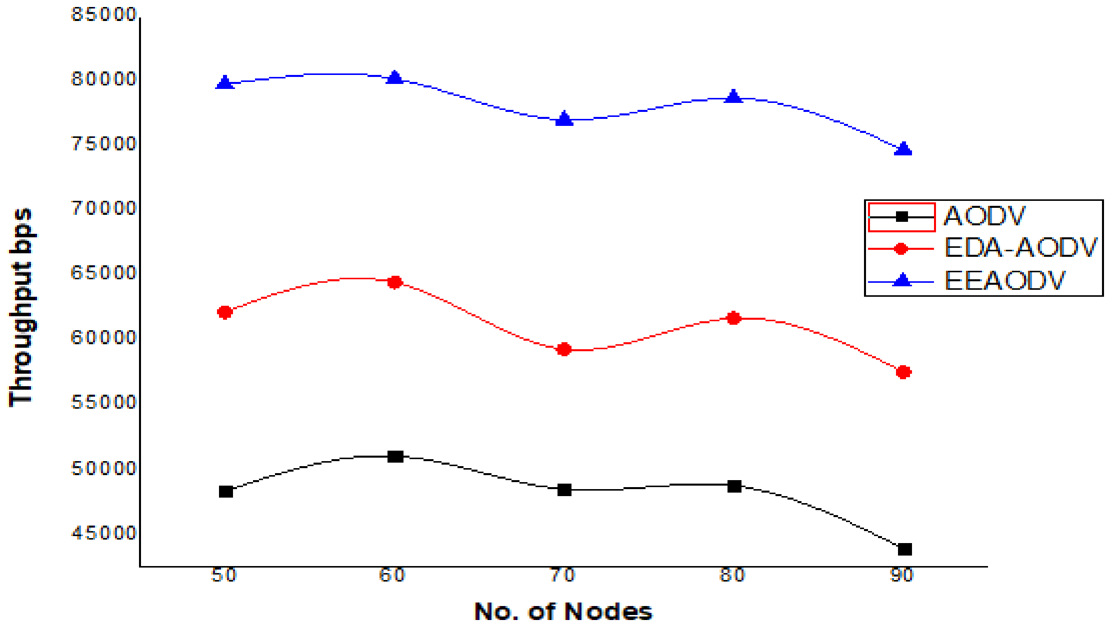

Figure 11: Throughput vs Number of Nodes

Figure 12 depicts number of alive nodes against the number of nodes in the network for the three protocols AODV, EDA-AODV and the proposed scheme EEAODV. Figure shows that for all the participating protocols, the number of alive nodes get decreased with increasing the total number of nodes in the network. The results show that the proposed scheme EEAODV out performs EDA-AODV and AODV as example at 50 nodes in the network, the average number of alive nodes for EEAODV is 37 nodes while for EDA-AODV is 18 nodes and for AODV is 12 nodes.

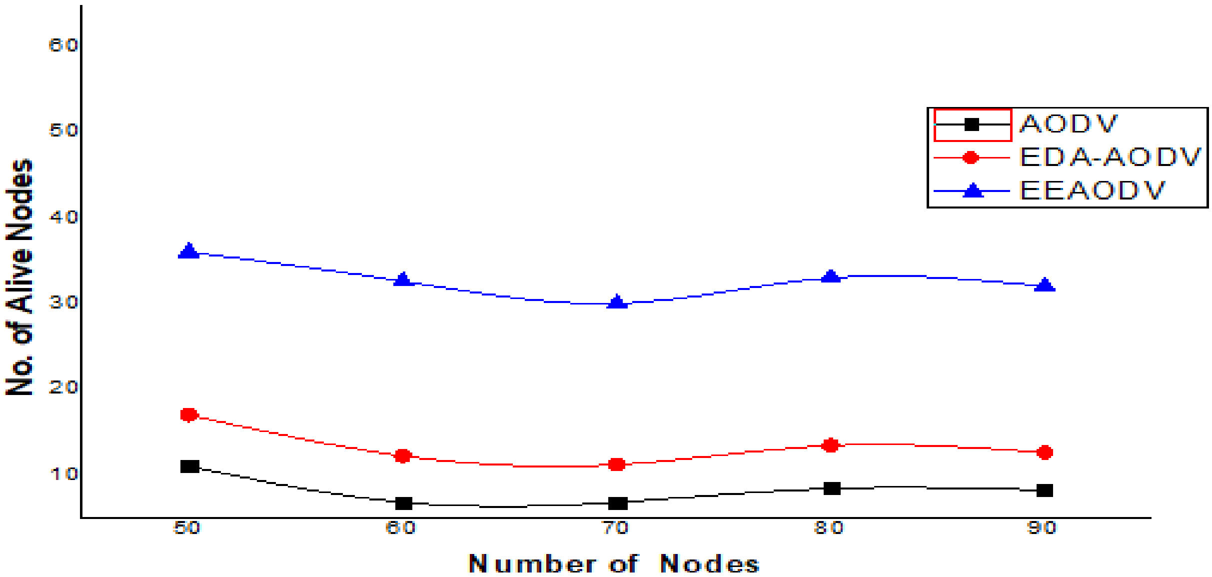

Figure 12: No. of Alive Nodes vs Number of Nodes

5. CONCLUSION

This article proposes a new scheme called EEAODV based on the standard AODV. The new scheme aims to prolong the lifetime of the network by using energy load balancing. To achieve that aim, the proposed scheme categorizes the participating nodes based on the residual energy of each node and then uses the super-increasing knapsack to calculate the energy weight of the candidate paths with respect to energy and hop count metrics. The proposed EEAODV has been compared with the existing schemes EDA-AODV and the standard AODV. The simulation results indicate that EEAODV outperforms EDA-AODV and standard AODV with respect to throughput and the number of alive nodes under different scenarios. In future work, we aim to secure the candidate routes to provide a secure and energy-efficient routing protocol and compare the proposed scheme with other existing schemes.

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