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Fault-tolerant Multi-path Routing with Enhanced Particle Swarm Optimization in MANET

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ABSTRACT

A MANET is a collection of self-contained mobile nodes which act as a network without the usage of a specialized platform.. Because of the battery-operated sensor nodes, each node carries less energy. Several routing strategies have been devised; however all of them have energy difficulties. Due to isolated grouping and a limited model, MANET is unable to prevent the problem. Various solutions are used to deal with various MANET failures; however it has been plagued by energy problems. As a result, a fault tolerant multipath routing technique known as the extended PSO algorithm was designed to address these concerns. The goal is to propose a fault tolerant multipath data transmission mechanism in MANET that is optimized. The created model included three stages: fault injection, Cluster Head selection and multipath routing. MANET nodes were first simulated. The fault injection phase is then sent into the simulated MANET nodes. The fault injection is carried out in accordance with the fault model on the nodes. The LEACH technique is then used to pick the optimal CH for energy optimization during the CH selection phase. Following that, multipath routing is performed using the Enhanced PSO algorithm to enhance the routing process and select numerous paths. Simulation part is done using NS3 simulation software.

General Terms

MANET, PSO, Fault tolerant, NS3

Keywords

MANET, Multipath routing, Fault tolerance, Cluster head selection, Energy

1. INTRODUCTION

MANET is self-functioned wireless module which is liable for beginning the communication and inhabit in self-directed mobile platform where the mobile node can send data between nodes with wireless interfaces without relying on third-party services. [1] .The MANET does not rely on specific platform. The few resources are attained that includes battery, and memory restrictions. [2] .MANET contains various applications like set of communication, rescue operations and data acquisition [3] .The goal of routing technique is to construct a effective path amongst nodes for transmitting data. However, the network is corrupted if routing is not directed properly and data loss can occur. Hence proper routing is essential to control whole network. [4] [5] Moreover, different topologies generated by nodes mobility impacts the consumed power to send data. Hence, the routing techniques handle the node mobility issues and altering topologies [[6] .

The solitary path acquires energy conservation and faces huge delay. To prevent these kinds of issues and to avoid network collapse, As a replacement, multipath routing is implemented. Multipath routing allows load traffic to make the most of available resources and bandwidth. Hence, there should be proper balance amidst energy and delay for acquiring improved efficiency in routing and selecting CH. Hence, delay, and energy evaluation helps to choose best path in routing [7]. The network was more sensitive to errors due to resource limits. The presence of multiple heterogeneous devices leads to the incidence of errors. The goal of the fault tolerant approach is to determine the occurrence of problems and to design a mechanism for dealing with them. The fault management layer is in charge of the entire problem handling process. Faulty nodes that rely on software failure can occur for a variety of reasons [8].

2. MOTIVATIONS

This section examines some traditional MANET fault-tolerant multipath routing strategies. The problem of approaches is discussed, as well as the difficulties that traditional fault tolerant multipath routing solutions confront. These problems and challenges have sparked the development of a new fault tolerant multipath routing system.

2.1 Review of the literature

The four classical fault tolerant multi-path routing approaches are enlisted. A link-disjoint multipath routing model has been devised to solve real-time optimization difficulties In this scenario, the method was used to discover the shortest path between two network points. However, no optimization approaches were used to maximize efficiency in this procedure. [9] .

AODTMDV approach for mobile ad hoc network with trust characteristics was presented. In this case, the method reduced attacks from malicious nodes while also improving the security of the network. The method suffered from over fitting issues. [10] .

To commence multipath routing in MANET, a trust-based topology-hiding multi - path routing mechanism has been devised. With the help of a security aspect, the technique was able to determine the security of each node. However, the technique did not able to offer security [11] .

Energy aware multipath routing based on Qos with MANET has been developed. In this method, the gravitational search algorithm with Particle Swarm Optimization was employed for choosing numerous paths. However, this method did not enhance network lifetime [12]. [13]

2.2 Challenges

The following are some of the challenges that traditional multipath routing techniques address:

• The problems with traditional techniques discovered that each node transmits data from source to destination with network capacity, which necessitates network collection. However, it may cause problems determining the current node's position, as well as node failure. [9].

• The topology disclosure problem is present in the multipath routing method. Multipath routing modifies each node's routing database and introduces numerous threats that can create network overhead [11].

• For routing multipath in MANET, [12] developed QoS-based energy conscious multipath routing. Because of the battery-operated devices in MANET nodes, there are energy limits. As a result, providing safe routing in a MANET becomes difficult.

3. SYSTEM MODEL

MANET is a self-configuring mobile node network that does not rely on existing infrastructure. Because of the battery-operated sensor nodes, each node in the network uses less energy. Numerous routing strategies have been created, however each method has been limited by the energy constraint.

Figure 1 presents a MANET model. Assume a MANET graph $G=(H,I)$ such that $H=\{k_1,k_2,\ldots,k_a,\ldots,k_d\}$ signifies a set of node and d expresses the total number of nodes in MANET. Here, I denotes a set of paths that join two nodes, and is denoted by $I=\{g_1,g_2,\ldots,g_h,\ldots,g_e\}$.Consider Q as a source node that transmits data packets to destination node R .

3.1 Faulty model

Permanent soft and permanent hard faults are two types of defects in the faulty model. “The permanent hard fault reveals that nodes $SN_U \in W, U=1,2,3,\ldots,W$ and time factor is given by $\beta=1,2,3,\ldots,Z$, then node SN_i for all-time instances $\forall_\beta SN_U(\beta)$ doesn’t always react to Cluster Heads. In soft fault, the $SN_U \in N$ where $U=1,2,3,\ldots,W$ contains sensor value SO_β for each time $\beta=1,2,3,\ldots,\beta$ As a result; the value of a sensor node $SN_U(SO_\beta)$ for all-time instances differs from the actual sensor value. X_t .The soft fault is given by,

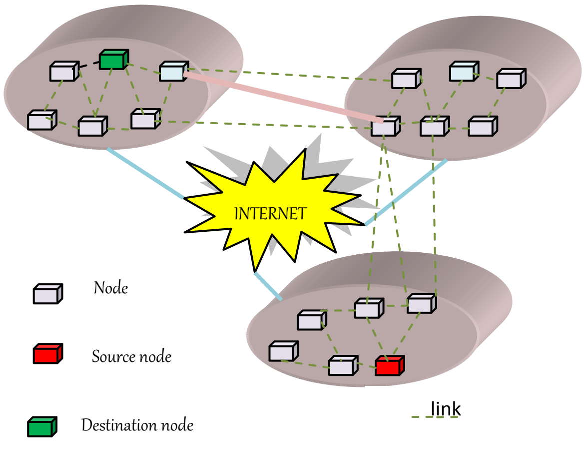

Figure 1 MANET system model

$$\forall_\beta SN_U(SO_\beta) \neq \forall_\beta SN_U(X_\beta) \qquad (1)$$

where, $SN_U(X_\beta)$ is actual nodes value, $SN_U \in W$ and $\beta=1,2,3,\ldots,\beta$ at certain time.

The consistency of SN where $SN_U \in W$ is computed using normal distribution. The fault model is developed using the normal distribution technique. Consider SN , in which $SN_U \in W$ contains sensor value $V_U(\beta)$ at β^{th} time, where $U=1,2,3,\ldots,n$ and $\beta=1,2,3,\ldots,Z$. For faulty node behavior SN_U , it is imperative to compute all sensor node values that is $\{V_U(\beta)\}_\beta^Z$. The SN is detected as actual data as well as error-prone data in β^{th} time. The sensor data value $V_U(\beta)$ undergoes normal distribution, denoted by W such that $(ac_U(\beta), n)$, where $ac_U(\beta)$ indicates sensor node’s actual data SN_U at β^{th} time and ϑ^2 is error data variance present at SN_U node. Hence, the SN’s data is expressed by,

$$SN_U(\beta)=ac_U(\beta)+\in r_U(\beta) \qquad (2)$$

Where, $\in r_U(\beta)$ is erroneous value at β^{th} time. Thus, the probability density function of normal distribution with sensor value $SN_U(\beta)$ is given by”, [13]

$$f(SN_U(\beta))=\frac{1}{\sqrt{2\vartheta_U^2\pi}}\times\exp\left(\frac{-(SN_U(\beta))-ac_U(\beta)^2}{2\times\beta_U^2}\right)$$

4. PROPOSED ENHANCED PSO FOR MULTI-PATH ROUTING

The aim of this study is to show how a MANET fault-tolerant multi-path data transmission system can be implemented. The suggested paradigm has three steps: fault injection, Cluster head selection, and multipath routing. The MANET nodes are first simulated, and then the fault injection phase is applied to the simulated MANET nodes. The fault injection to the nodes is carried out in accordance with the fault model. Following that, the CH selection phase is completed using the LEACH procedure to choose the optimum CH for energy optimization. The suggested Enhanced PSO method is then used to identify numerous pathways for multipath routing in order to improve the routing process. Fig. 2 shows the structure of the proposed multipath routing paradigm.

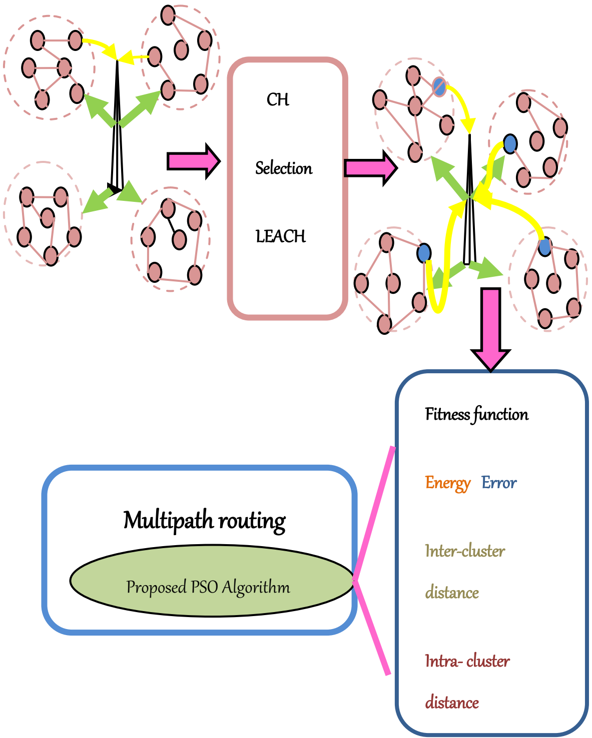

Figure 2structure of proposed multipath routing

4.1 LEACH protocol for CH selection

To deliver data to the BS, the LEACH protocol [14] [15] employs a wide sensor network with equal-energy nodes. As a result, the best CH is chosen for data collection and transmission to BS. As a result, LEACH assists in the selection of optimal CH, resulting in a node with greater energy. As a result, the LEACH protocol uses random CH rotations to ensure that energy is distributed uniformly among sensor nodes. Furthermore, LEACH is organized in a specific way, and LEACH runs in rounds after CH is specified. For each round of size, a group of Cluster Head is determined, where are the total nodes in rounds. The following is how the threshold is defined: The proposed multi-path routing's structure

$$\tau(w)=\begin{cases}\dfrac{t}{1-t\times(c \bmod \frac{1}{t})} & ;if\ \ e\in\alpha\\[2ex] 0 \quad ;Otherwise & \end{cases}$$

(4)

Where, α is node, that is not Cluster Head, t refers percentage of CH, and c is updated period of current topology. As a result, LEACH's CH is given by,

$$K=\{K_1,K_2,\cdots,K_g,\cdots,K_o\}\ \ ;1\le g\le o$$

(5)

Where, o is total CH.

5. MULTIPATH ROUTING WITH ENHANCED PSO

The Enhanced PSO method, which is a combination of adaptive concepts in PSO, is used for secure multipath routing The subsections look at fitness functions, solution encoding and the proposed Enhanced PSO.

5.1 Encoding method

The solution vector denotes the solution modeling discovered by applying the proposed Enhanced PSO. The solution vector contains paths that participate in data transmission routing between nodes. Consider Q and R represents a source node and targeted node and count of paths needed for attaining destination from source node is expressed by e. From e paths, the paths chosen for beginning the transmission of data amidst nodes are expressed in the solution vector. Here, o express paths index, which relies in $1\le o\le e$. Fig. 3 express encoding method with Enhanced PSO.

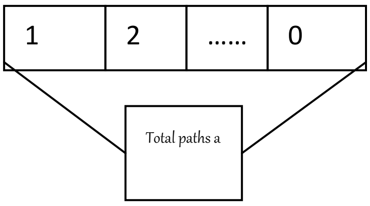

Figure 2 solution encoding with Enhanced PSO algorithm

5.2 Fitness function

Within MANET, particular criteria such as inter cluster distance, error, link quality, intra cluster distance, delay, and energy are used to assess fitness. The proposed CIIEHO algorithm's fitness is modified to find the best path.

The following is how fitness is defined. :

$$Fitness=\frac{1}{6}\left[\partial+(1-M^{inter})+M^{intra}+\varepsilon+L^{Q}+E\right]$$

(6)

Where, ∂ is delay, M^{inter} refers inter cluster distance, M^{intra} represents intra cluster distance, ε is usage of energy, L^{Q} symbolize quality of link, E express sensor node's erroneous value

5.2.1 Delay:

The number of nodes in a cluster as a percentage of the total number of nodes and is denoted by ∂ , and is expressed as,

$$\partial = \frac{1}{k}\sum_{n=1}^{k}\frac{C_n}{q} \tag{7}$$

Where, C_n symbolize node's count in n^{th} Cluster Head, q indicates total number of nodes, and k denotes number of Cluster Heads.

5.2.2 Inter cluster distance:

It is defined as a distance amongst chosen clusters, and is expressed as,

$$M^{\text{inter}} = \frac{1}{\alpha_1 * k}\sum_{n=1}^{k}\sum_{\substack{n=1\\ n\neq m}}^{k} M(n,y) \tag{8}$$

Where, α_1 denotes normalizing factor & $M(n,y)$ represents distance among n^{th} and y^{th} Cluster Head.

5.2.3 Intra cluster distance:

It is distance between Cluster Head and nodes and denoted by,

$$M^{\text{intra}} = \frac{1}{\alpha_2 * q * k}\sum_{h=1}^{q}\sum_{n=1}^{k} M(h,n) \tag{9}$$

Where, $M(h,n)$ shows distance between h^{th} and n^{th} Cluster Head, and α_2 represents normalizing factor.

5.2.4 Consumption of energy:

Consumption of energy is formulated by, $\varepsilon_{cons} = \frac{1}{k}\sum_{n=1}^{k}\varepsilon_n$

(10)

Where, ε_n represents consumption of energy of n^{th} Cluster Head.

5.2.5 Link quality:

It is the measure of quality of data packets received by the receiver, & is expressed by,

$$L^Q = \frac{P_\ell}{O_d} \tag{11}$$

Where, P_ℓ defines power constant between source node and destination node and O_d defines the distance between receiver and transmitter.

The purpose aims to determine how accurate sensor nodes are If a problem emerges, as error E = high, the node might request that the BS in enable sleep mode instead of participating in the transmitting data. This strategy aids in the prevention of inaccurate data accumulation by sensor nodes that represents the faulty model. The network problem handling is completed here according to the error value E . If $E = high$, then due to low energy, the sensor transmits an error value As a result, sensor nodes with only a high error value will enter a sleep mode and stop transmitting data..

5.3 The proposed enhanced PSO algorithm's algorithmic steps

The proposed adaptive notion is included into the PSO algorithm to create an enhanced PSO algorithm. The particles have inspired the PSO [16] [17]. The PSO algorithm's simplicity allows for simple computations and comprehension. The exploration and exploitation phases are controlled by PSO, resulting in a global optimal solution with higher convergence rates. The self-adaptive constants alter the control settings during update without the need for human interaction. As a result, improved PSO improves convergence to the global optimum, allowing for additional algorithm improvement. As a result , including the adaptive idea into PSO aids in the generation of global optimal data routing solutions. The following is the algorithmic procedure: 3 phases in the proposed improved PSO algorithm

5.3.1 : First step- Initialization:

$$C = \{C_1, C_2, \ldots, C_j, \ldots, C_x\} \tag{12}$$

Where, X denotes total solution, and C_j refers the j^{th} solution.

5.3.2 : Second step-Compute fitness:

The fitness is already defined in section 4.2

.

5.3.3 : Third step- update equation's determination:

The standard equation of PSO is given as.

$$C_i(t+1) = C_i(t) + V_i(t+1) \tag{13}$$

Where, $C_i(t)$ is current position of particle and $V_i(t+1)$ symbolize velocity of particle at iteration $t+1$.

Where velocity refers to,

$$V_i(t+1) = WV_i(t) + R_1Q_1\left[\hat{C}_i(t) - C_i(t)\right] + R_2Q_2\left[G(t) - C_i(t)\right] \tag{14}$$

Where, Q_1, R_1, Q_2, R_2 are constant and $G(t)$ is global best solution. Here, the constant R_1 is made adaptable.

The self-adaptive constant is represented as R_1 and therefore are formulated based on the positions as,

$$R_1 = \left(1 + \left(\frac{1-w}{1+w_{\max}}\right)\right) \quad (15)$$

Where, w indicate current round and $w_{\max}$ indicate maximum rounds.

5.3.4 : Step four-Find best solution

After calculating the updated position, each solution's fitness is re-evaluated, and the solution with the highest fitness is designated as the best solution.

5.3.5 : Fifth step- Termination

The algorithm is discontinued when it reaches the maximum number of iterations $w_{\max}$ or when no further fittest solutions can be found.

6. RESULTS AND DISCUSSIONS

The analysis of Enhanced PSO is done using PDR, delay and throughput

Figure 4 displays the analysis of techniques with PDR by altering the number of iterations. For iterations10, the PDR evaluated by AODTMDV, and Enhanced PSO are 0.7001 and 0.7312. Also, when number of iterations is 30, the PDR evaluated by AODTMDV, and Enhanced PSO are 0.7312 and 0.7721.

Figure 5 displays the analysis of techniques with delay by altering the number of iterations. For rounds 10, the delay evaluated by AODTMDV, and Enhanced PSO are 108.23, 90.03. Also, when number of iterations is 30, the delay evaluated by AODTMDV, and Enhanced PSO are 182.13, 150.48.

Figure 6 displays the analysis of techniques with Throughput by altering the number of iterations. For rounds 10, the Throughput evaluated by AODTMDV, and Enhanced PSO are 98.12, 112.70. Also, when number of iterations is 30, the Throughput evaluated by AODTMDV, and Enhanced PSO are 267.10, 502.13.

Table 1 Comparative analysis of AODTMDV and Enhanced PSO

	No. of iterations	AODTMDV	Enhanced PSO
PDR	10	0.7001	0.7312
	30	0.7312	0.7721
DELAY	10	108.23	90.03
	30	182.13	150.48
THROUGHPUT	10	98.12	112.70
	30	267.10	502.13

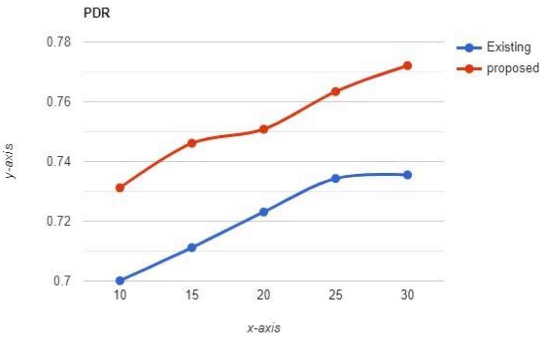

Figure 3 Analysis with PDR

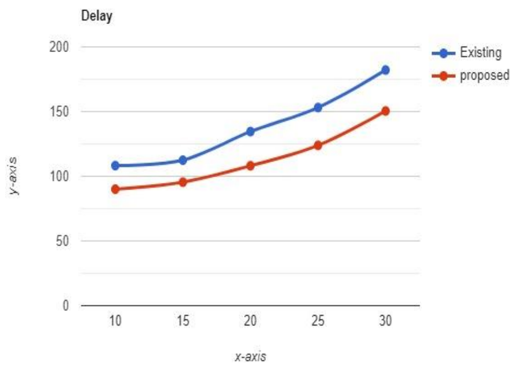

Figure 4 Analysis with delay

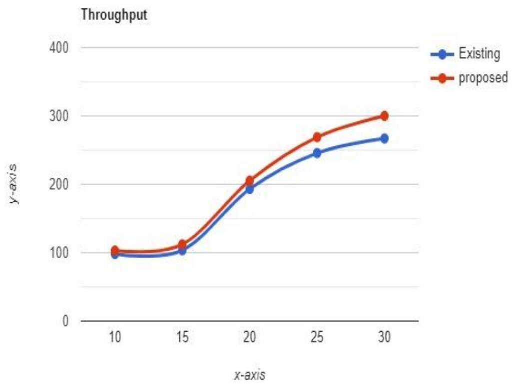

Figure 5 Analysis with Throughput

7. CONCLUSION

The enhanced PSO algorithm is a method that has been devised. The goal aims to present an optimized fault tolerance multi path data transmission mechanism for MANET. Three steps were implemented in the developed model: fault injecting, Cluster Head selection, and multi path routing. MANET nodes are then simulated, and then they are supplied through into faulty injection stage. The faulty injection to the nodes is carried out here in accordance as per the faulty model. The LEACH procedure can then be used in a Cluster Head formation step to select the best CH for energy optimization. Following that, the multipath routing process is improved by employing the Enhanced PSO algorithm to select multiple paths. The Enhanced PSO resulted in improved distributed sensor and helps to improve the lifetime of network. In addition, it enhances efficiency of energy by reducing the complete energy consumption.

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