Dynamic Secure Multipath Routing in Wireless Sensor Networks using Modified Simulated Annealing based Particle Swarm Optimization

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ABSTRACT
Routing in wireless sensor network has entirely different requirements compared to the routing requirements of a normal network. The complexity arises from the requirements of security, load balancing, resource constraints and failure handling. This paper presents a fast, secure and dynamic route generation technique for wireless sensor networks using metaheuristics for route generation. A modified form of Particle Swarm Optimization technique is used for route generation. In-order to overcome the problem of local optima, PSO is hybridized by incorporating Simulated Annealing in its local selection process. Hybridization also speeds up the route selection mechanism, thereby reducing the time overhead to a maximum extent.

Keywords
WSN Routing; Secure routing; PSO; Simulated Annealing; Multipath Routing

1. INTRODUCTION
Several efforts were taken to provide a secure WSN [1]. The major requirements of a routing algorithm in a WSN is not just to provide a secure route. It has several other constraints such as uniform load on all nodes to provide longevity to the network, reducing the average network charge in a balanced manner such that the nodes remain altruistic for maximum possible time and to provide dynamicity in the route selection process such that the route generated is secure [2]. The dynamic and resource constrained nature of operations in WSN makes the process complex

The process of route identification has to be dynamic in WSN. Unlike the usual routing methodologies, the routes generated in WSN needs to be balanced, utilizing the available nodes in a uniform manner. A balance has to be achieved between the number of hops to be used for transmission and the reuse levels [3]. These requirements can be effectively satisfied by metaheuristics, hence this paper utilizes metaheuristics for the routing process. Another major constraint faced by WSNs is the uneven charge dissipation [4]. Remnant charge in WSN nodes plays a crucial role in determining the behavior of a node. Hence energy efficiency of an algorithm plays a crucial role in the routing technique to be used in the network. This paper presents an effective low latency dynamic routing technique that performs efficient and balanced routing in WSNs. Route generation is performed using Particle Swarm Optimization (PSO) [5]. PSO is modified and hybridized using Simulated Annealing (SA) to provide an energy efficient route generation technique.

2. RELATED WORKS
Routing has been an issue prevalent since the beginning of the process of networking. However, routing in WSN have certain specific demands. Secure routing is ensured in two different ways; by securing the information transmitted and by providing a secure routing path. This section discusses some of the most recent techniques proposed to enhance security in the routing process.

An Elliptic Curve Cryptography (ECC) and homomorphic encryption based secure routing scheme is presented by Elhoseny et al in [6]. It works on the basis of the GASONeC algorithm based on Genetic Algorithm. An authentication and integrity based routing technique was proposed by Senthil kumaran et al in [12]. Other such techniques integrating security mechanisms in the transmissions include [13, 14]. A dynamic routing protocol specialized in multipath routing is presented by Kaur et al. in [7]. This technique uses Distributed Hash Tables (DHT) to perform the routing process. A minimum transmission based multicast routing technique is presented by Zhang et al in [8]. This technique is based solely for industrial applications and utilizes a heuristic based routing mechanism for the route selection process. Other similar multicast based routing approaches for industrial applications include [9, 10].

A network lifetime enhancement based routing technique is presented by Raja et al. in [11]. This technique uses Game Theory based Cooperative MIMO routing scheme to even out the energy consumption in the network nodes. The limitations of this technique is that it requires fixed number of nodes. The nodes are clustered and cluster heads are identified. This entire process is carried out once and modifications in the network topology is not accepted. Other lifetime enhancement techniques for WSN include [19, 20]. An adaptive clustering based routing technique was proposed by Marappan et al. in [15]. This technique operates on the basis of data aggregation. Other data aggregation based techniques include [16, 17]. A load balancing based congestion detection routing technique is presented by Ahmed et al in [18].

3. DYNAMIC SECURE MULTIPATH ROUTING IN WSN USING MODIFIED SIMULATED ANNEALING BASED PSO
Secure routing is the major requirement of current WSNs due to the vulnerability brought about by their deployment regions [23]. Safety in transmission can be brought about in the

routing process. This leads to the elimination of the usual shortest path algorithm due to its static nature [24, 25]. Incorporating dynamicity will not only enhance the network from the aspect of security, but also aids in load distribution, leading to longevity of the network. The architecture for route generation using Simulated Annealing based PSO is presented in Fig 1.

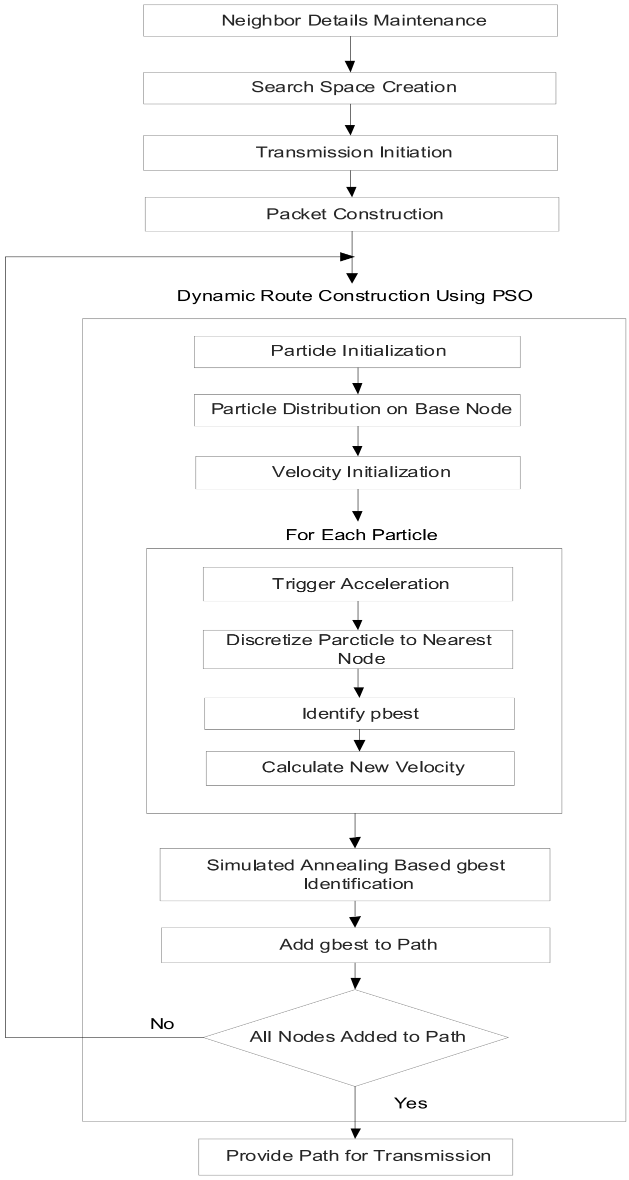

Fig 1: Dynamic Secure Multipath Routing in WSN using Modified Simulated Annealing based PSO

The base network creation is followed by the creation of search space using the neighbor details maintained by the nodes. Path creation is initiated after the initiation of the transmission. The transmission initiation is followed by packet construction. This initiates the route identification module.

3.1 Dynamic Route Generation using Modified Simulated Annealing based PSO

The first phase of route identification phase begins by identifying the search space boundaries and initializing the particles within the search space boundaries. The particles are initially deployed in the node that has initiated transmission. However, they are dispersed around using the velocity component after acceleration.

The velocity component is initialized within the boundaries of the search space using eq 1.

$$V_i \sim U(-|b_{up} - b_{lo}|, |b_{up} - b_{lo}|) \quad (1)$$

Acceleration of particles is triggered and the particles are dispersed. PSO operates on continuous space, whereas the current requirement of routing requires operations in discrete space. Hence the proposed approach incorporates a discretization phase into the working process of PSO. The particles are discretized using eq 2

$$P' = \min\left(\sum_{j=1}^{n}\left(\sum_{k=1}^{d}\sqrt{\left(P_{ik} - N_{jk}\right)^{2}}\right)\right) \forall i = 1 \ to \ p \quad (2)$$

This phase ends with the particles landing on a distinct node. The pbest is identified and a new velocity is assigned to each of the particles.

The end of this iteration results in a set of pbest particles identified. Simulated Annealing [21,22] is used to identify the gbest value from the set of pbest values. The gbest value is added to the final path. This process is repeated until the destination node is reached.

This is a single path identified for a single packet. A dynamic path is identified for each packet contained in the transmission. Each packet is transmitted through the dynamically created route, hence making the routing process secure and distributed. This leads to the elimination of node depletion due to continuous usage of a single node for transmission. Hence increases the lifetime of the network.

4. RESULTS AND DISCUSSION

Experiments were conducted on a network with 30 nodes, each with the same amount of energy. Transmissions were carried out on this network in two categories. The initial set of transmissions were carried out with random starting nodes and the process ends after a complete route containing all the nodes is created. The next set of transmissions were carried out with defined starting and ending nodes. Efficiency of the algorithm was measured in terms of selection overhead and load distribution among the nodes.

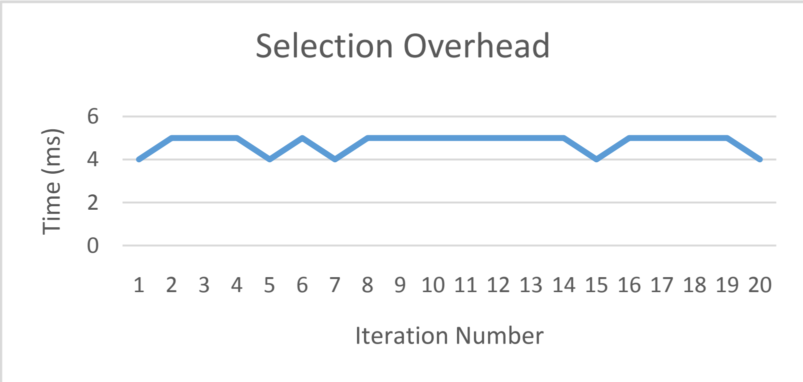

Fig 2: Selection Overhead

The selection overhead occurring in the transmissions is presented in figure. The experiments were conducted and 20 transmissions were recorded. Time taken for generating each of the routes were recorded and identified as the selection overhead. It could be observed that the proposed PSO SA technique exhibits a maximum selection overhead of 5ms and a minimum selection overhead of 4ms. This is a very negligible time, hence the proposed approach is considered to be a suitable technique for dynamic transmission on a WSN.

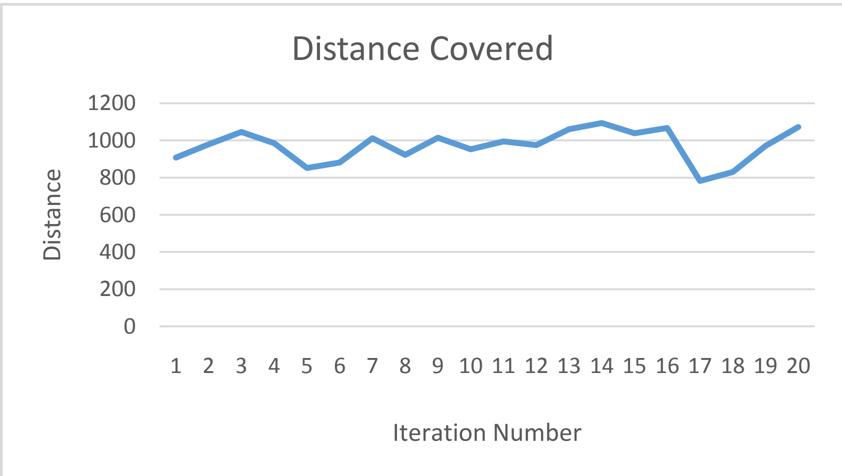

Fig 3: Distance Covered

Distance covered by the proposed PSO SA approach when identifying a route covering all nodes in the network is presented in figure. It could be observed that an average distance is maintained by the system without exhibiting high fluctuation levels. This shows the stability of the proposed PSO SA architecture making it ideal for the routing process.

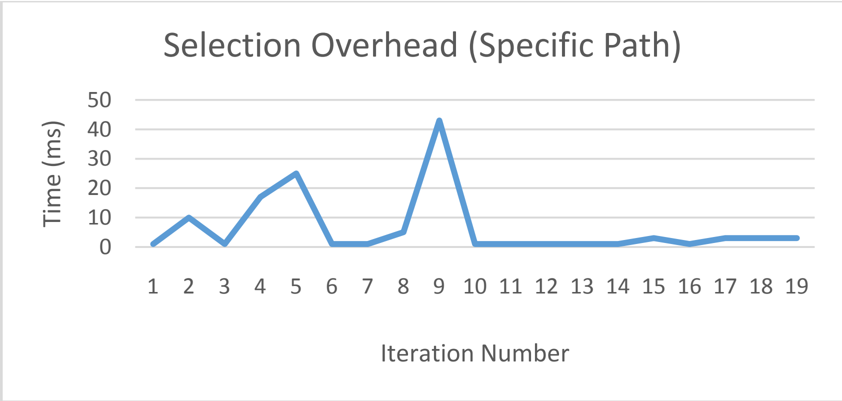

Fig 4: Selection Overhead (Specific Path)

Selection overhead experienced when applying PSO SA on a specific start and end node requirement is presented in figure. It could be observed that the time taken for the process varies between 1ms and 45ms. This variation level is due to the presence of identifying the end node. However, even the increased computation has a maximum overhead level of 45ms, which is also an acceptable waiting time level for a packet to obtain the transmission route.

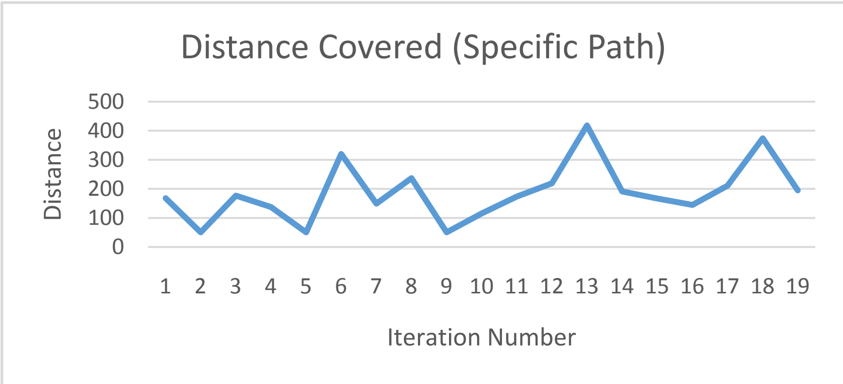

Fig 5: Distance Covered (Specific Path)

Distance covered on generating paths between defined nodes is presented in figure. It could be observed that the proposed PSO SA has exhibited minimum distances for maximum number of transmissions. High levels occurs due to the dynamic nature of the approach. However these peaks can be observed only in three transactions making the approach reliable and fast.

5. COMPARATIVE STUDY

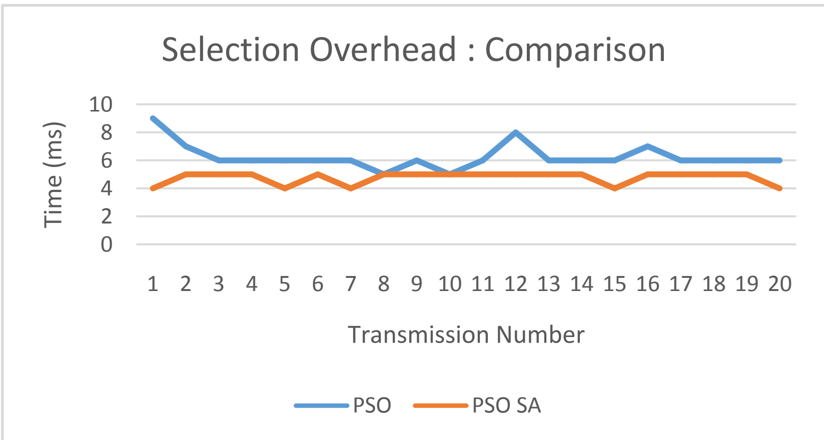

Fig 6: Selection Overhead : Comparison

A comparison of the selection overhead between PSO and the proposed PSO SA is presented in figure. It could be observed that the proposed approach exhibits a maximum overhead of 5ms, while the minimum overhead exhibited by PSO itself is 5ms, exhibiting the efficiency of the proposed approach.

6. CONCLUSION

This paper presents a metaheuristic based routing solution for providing dynamic and secure routes in a WSN. The proposed architecture uses a modified form of Particle Swarm

Optimization algorithm, incorporating Simulated Annealing in its local selection process to eliminate getting struck in local optima. The proposed technique is designed as a dynamic route generation mechanism; hence it provides an additional advantage of improved security from packet sniffing attacks. Limitations of this approach include the absence of network traffic based analysis in identifying the routes. If a route has congestion, then the particular packet has to be retransmitted. Though this occurrence is rare, it is not handled by the proposed PSO SA. Future enhancements of this technique can include mechanisms to provide congestion control, making the transmission paths more reliable. The algorithm can be further improved by incorporating trust levels of neighbors to perform trust based routing, hence making the probability of retransmission very low.

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He served as Principal Investigator for UGC and AICTE, New Delhi funded innovative, major and minor research projects worth of 1.7 crore especially in the area of Intelligent systems, Data Mining and Soft Computing. **He is the recognized supervisor for research programmes in Computer Science leading to Ph.D and MS by research in several universities including Anna University Chennai, Bharathiar University Coimbatore, Manonmaniam Sundaranar University Tirunelveli, Periyar University Salem, Mother Teresa University Kodaikanal and many Deemed Universities.** He has got 78 papers on his credit in international and national journals and 13 scholars obtained Ph.D under his guidance and supervision. He has been serving as Editor In Chief for the International Journal of Research and Reviews in Artificial Intelligence (IJRRAI) United Kingdom and serving as reviewer and member of editorial in accredited peer reviewed national and international journals including Elsevier Journals.