

HARNESSING PSO AND GA FOR CONGESTION CONTROL IN HIGH-SPEED WIRELESS SENSOR NETWORKS

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Abstract

Sensor and sink nodes create wireless sensor networks. Traffic congestion caused by WSN data transfer causes bigger packet losses, low throughput and excessive energy consumption. This work proposes a hybrid congestion management approach using genetic algorithm and particle swarm optimization. The new approach is simulated and compared to established methods. The suggested system dramatically improved performance metrics. The suggested system of interest increased to 94% detection efficiency, 91% network lifespan, 106 J energy usage, and 22 packet loss rate. The hybrid approach avoided wireless sensor network congestion and managed traffic.

Key words: genetic algorithm, particle swarm optimization, wireless sensor networks, end-to-end delay, detection efficiency, energy consumption

Introduction. Wireless Sensor Networks (WSN) rely on sensor and sink nodes. Portability, low cost, and ease of deployment make WSNs popular. The sink nodes receive data wirelessly from sensor nodes across the network [1,2]. Data packets are used to quickly convey the gathered physical information. WSN designs place sensor and sink nodes in the sensor field. The sink node requests data from the neighbouring sensor node. The sensor node records the physical attributes and delivers a data packet to the sink node. This ensures the sink node receives the desired data. WSNs have applications in healthcare, military surveillance, and weather monitoring. In such cases, several sensor nodes collect

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and communicate data. Congestion in the network may occur when several nodes are sending and receiving data at the same time [3]. Traffic slows a wireless sensor network. Throughput, data packet loss, and channel capacity decrease. Congestion management and reduction need congestion control solutions [4]. These methods locate, alert, and alter congestion to improve network speed and data transmission [5].

Congestion management should lengthen network life, reduce energy consumption, boost throughput, and reduce delays and data packet loss. These objectives must be accomplished for real-world WSNs to work. Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) based hybrid optimization techniques may solve these difficulties. Hybrid PSOGA (HPSOGA) is useful in energy-efficient data aggregation, routing protocol design, sensor placement, clustering, spectrum sensing, and job scheduling. The hybrid technique uses GA's tremendous search capabilities and PSO's fast space exploration and exploitation. This blend optimizes WSN power utilization, network lifetime, data routing, and resource allocation based on WSN capabilities and limits.

Related works. Researchers have focused on WSNs research, applications, and congestion control. These components have been critically examined to determine their usefulness [6]. WSN nodes can detect events, compute, and communicate. Sensor and sink nodes still face insurmountable challenges in information routing and dissemination and power management. Resolving these issues requires efficient and powerful routing methods and network topologies. WSNs are chosen for their quick deployment, fault tolerance, flexibility, cost reduction, and high sensing capacity. However, WSN deployment locations change often, creating new issues. The changing environment might cause data transmission abnormalities. Hardware, software, or node overloading may cause these anomalies [7]. Sinks may be placed in appropriate locations to reduce some of these issues. WSNs and traffic congestion may be improved. Several queue-based strategies have been developed to manage congestion [8]. Congestion and network node count are linked [9]. The necessity for early congestion detection and rapid relief is essential [10]. Queuing theory may help reduce application-level congestion, which degrades Quality of Service [11]. The Healthcare Aware Optimized Congestion Avoidance and Control Protocol fall into this category [12]. The Delay-Constrained Congestion Control algorithm [13], Interference-Aware Congestion Control protocol [14], Hierarchical Tree Alternative Path algorithm [15], type 2 fuzzy logic-based protocol [16], and PSO-based congestion control scheme [17] are other proposed protocols. GA may help WSNs regulate traffic intelligently [18,19]. For energy clustering and stability, cognitive radio spectrum networks use PSO [20]. These protocols have repeatedly proven that effective congestion control may increase network performance. Each protocol has distinct downsides. Recently, PSO and GA have been intensively investigated for optimization. This research combines the two to create a novel strategy.

Materials and method. Proposed HPSOGA network model. High-speed source and sink node sensors clog WSN traffic. PSO chooses network-optimal nodes for HPSOGA. GA controls data transfer, initializes the network population, maximum iterations, and node velocities. Then assign data transmission time slots to each node, distribute them equitably to reduce congestion, and generate the transmission schedule matrix “S” with sensor node as row and time slot as column. Calculate packet queue length, bandwidth, and neighbourhood network congestion. Then determine the energy consumed $E(i)$, for each i -th node. For the i -th node, the fitness function is evaluated through the combination of congestion level $C(i)$, and energy consumption $E(i)$. Select the sensor nodes with lowest fitness values to form the regimen, determine its size R , based on the available resources and network constraints. Implement the matrix S for the selected regimen, and transmit the data packets from the sensor nodes within in the assigned time slots according to the schedule. Finally, invoke PSO and GA techniques to optimize the network performance through PSO and GA. Optimize the network by collecting the feedback from congestion levels $C(i)$, energy consumption $E(i)$, and packet drops. The following expressions are used to minimize the traffic congestion:

$$(1) \quad \begin{aligned} \min f(x) &= \text{total_traffic_congestion}, \\ x(t+1) &= wx(t) + c_1r_1(\text{pbest} - x(t)) + c_2r_2(\text{gbest} - x(t)), \end{aligned}$$

where

- $f(x)$ is the traffic density needed to be minimized;
- $x(t)$ is the traffic of the i -th node at t instant;
- $x(t+1)$ is the traffic at the i -th node at $t+1$ instant;
- w is the weightage given to the traffic;
- c_1 and c_2 are cognitive coefficients;
- r_1 and r_2 are the random numbers;
- pbest is the particle’s best solution so far;
- gbest is the global best solution so far.

Update the function $x(t)$ through the following equation

$$(2) \quad x(t) = x(t) + x(t+1).$$

The new $x(t)$ is considered the fittest individual from the traffic function, and apply the GA. Now through crossover functions, new offsprings are generated for this $x(t)$, through the next equation

$$(3) \quad \text{Offspring } x(t) = \text{crossover}(x(t), x(t-1)).$$

Mutate the offspring $x(t)$ through equation

$$(4) \quad \text{Offspring } x(t) = \text{mutation}(\text{offspring}(x(t-1))).$$

Evaluate the fitness of the offspring in equation (4).

In order to get the best performance, update the personal and global best positions through the following equations

$$(5) \quad \text{Fitness}(\text{offspring}(x(t))) > \text{fitness}(\text{pbest}(x(t))) : \text{pbest}(x(t)) = \text{offspring}(x(t)),$$

$$(6) \quad \text{Fitness}(\text{offspring}(x(t))) > \text{fitness}(\text{gbest}); \text{gbest} = \text{offspring}(x(t)).$$

Results and discussion. Figure 1 shows 100-node network simulator simulation of HPSOGA congestion control strategy. Figure 2 shows the system performance based on throughput, packet loss rate, energy utilization, end-to-end latency, network life time, and detection efficiency for various node sizes. From 20 to 100 nodes, HPSOGA detection increased from 80% to 94%. Forty, 60, and 80 nodes had 84%, 88%, and 90% simulated detection efficiency. Network longevity was 85% at 20 nodes and 91% at maximum nodes. Nodes 40, 60, and 80 had 88%, 89%, and 90% network lifespans. A good WSN reduces packet loss. HPSOGA lost 12% of packets to 20 nodes. Data transmission to 100 nodes lost 22% of packets. The recommended system lost packets at 16%, 19%, and 21% when sending data

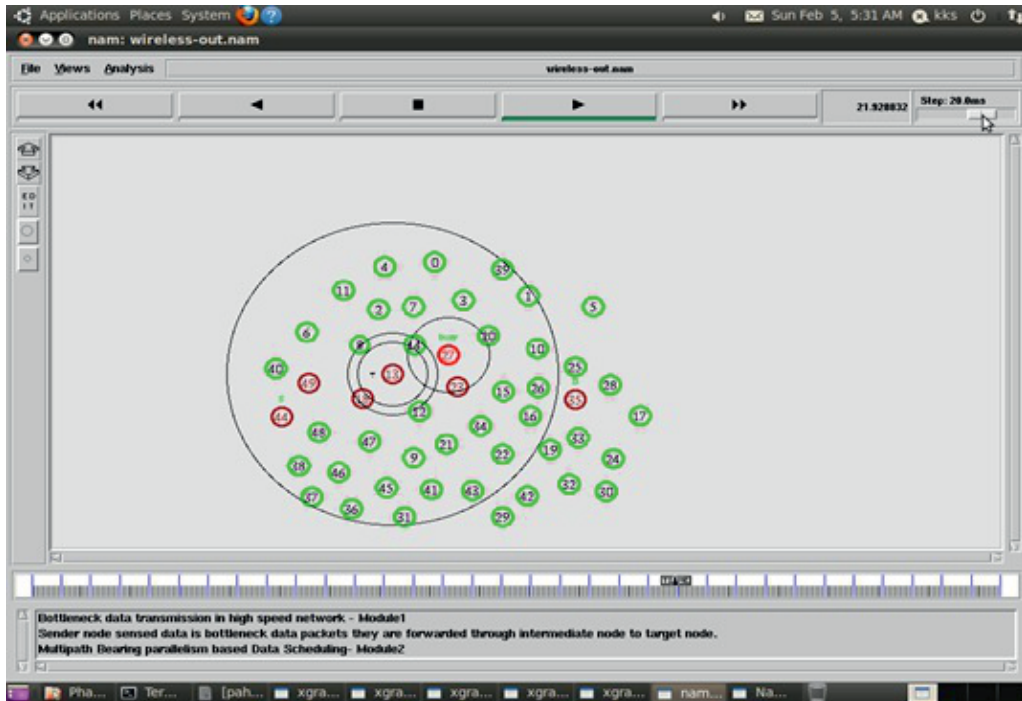


Fig. 1. Simulation results of the proposed HPSOGA congestion control scheme

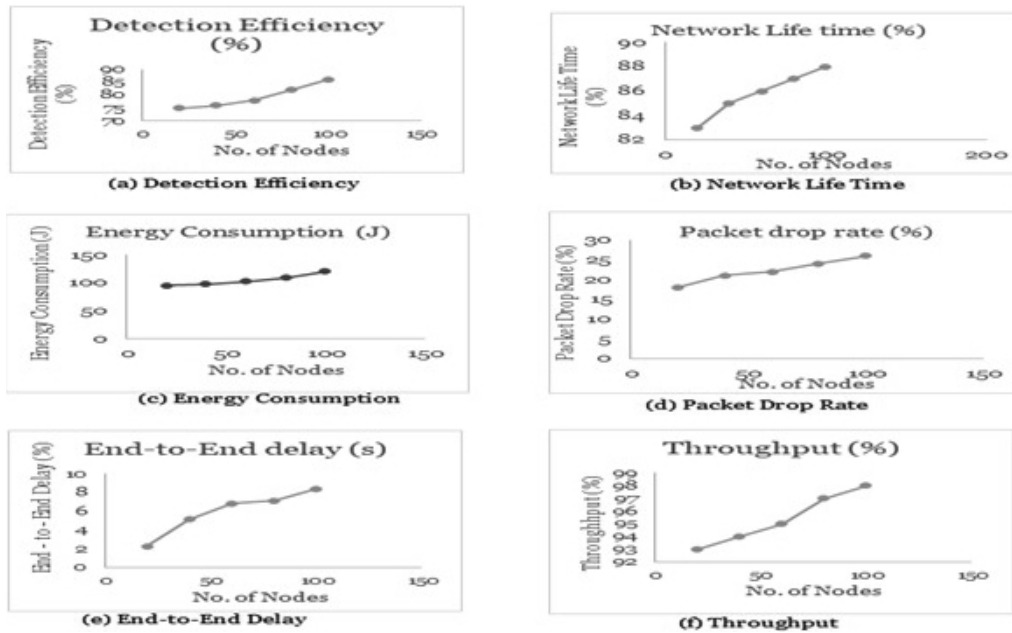


Fig. 2. Performance analysis of HPSOGA scheme

to 40, 60, and 80 nodes. HPSOGA-optimized WSN delivered data between 20 nodes in 1.76 s. Forty, 60, 80, and 100 nodes took 4.21, 4.99, 6.02, and 7.61 s. As nodes increased, HPSOGA optimized data transmission time. Twenty nodes had 94% throughput, 100 nodes 98.7%. Forty, 60, and 80-node throughput was 94.5%, 95.5%, and 97.2%. These statistics suggest high system throughput. Node count increases congestion, data drop rate, end-to-end latency, and throughput. Optimized systems must increase channel capacity as nodes proliferate to maintain throughput. HPSOGA's WSN technology avoids bandwidth increases. Thus, the system optimizes bandwidth to increase throughput.

Table 1 and Figure 3 compare the HPSOGA strategy to the PSO-based congestion mechanism and fuzzy-based technique. HPSOGA detects better than Type 2 Fuzzy and PSO Congestion Control (PSOCC) in all node configurations. The method increases detection efficiency by 1–8% and outlives Type 2 Fuzzy and PSOCC. It boosts network longevity by 5–13%. HPSOGA lowers packet loss by 10–18% and outperforms Type 2 Fuzzy and PSOCC utilizing 2.5–3.7 s less round-trip time. HPSOGA has superior throughput than Fuzzy and PSOCC. HPSOGA's energy management keeps the WSN running long without refuelling and its energy efficiency is shown by the network's durability. HPSOGA surpasses Type 2 Fuzzy and PSOCC in detection efficiency, network lifetime, energy consumption, packet loss, end-to-end latency, and throughput. These findings suggest HPSOGA-based congestion management is preferable.

T a b l e 1

Comparative analysis of various congestion control schemes with proposed HPSOGA

Nodes	Detection efficiency (%)			Network life time (%)			Energy consumption (J)		
	Fuzzy	PSOBCC	HPSOGA	Fuzzy	PSOBCC	HPSOGA	Fuzzy	PSOBCC	HPSOGA
20	72	75	83	74	83	85	112	95	90
40	73	76	84	75	85	88	121	98	92
60	75	78	88	77	86	89	124	103	98
80	78	82	90	78	87	90	132	109	102
100	81	86	94	79	88	91	145	121	106

Nodes	Packet drop rate (%)			End-to-End delay (s)			Throughput (%)		
	Fuzzy	PSOBCC	HPSOGA	Fuzzy	PSOBCC	HPSOGA	Fuzzy	PSOBCC	HPSOGA
20	22	18	12	3.45	2.25	1.76	91	93	94
40	28	21	16	6.72	5.16	4.21	92.5	94	94.5
60	32	22	19	7.89	6.87	4.99	94.3	95	95.5
80	36	24	21	9.02	7.12	6.02	96.2	97	97.2
100	40	26	22	10.45	8.43	7.61	96.8	98	98.7

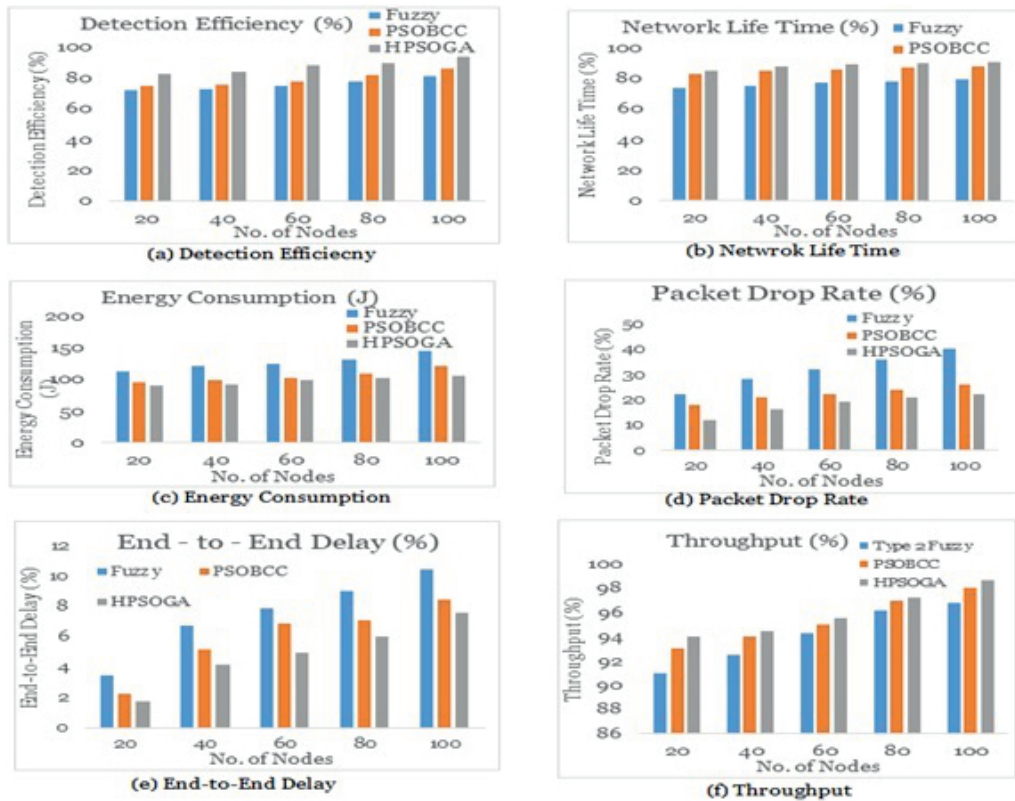


Fig. 3. Comparative analysis of schemes of interest

Conclusion. HPSOGA based network congestion scheme has been proposed for WSN. The proposed scheme was compared to Type 2 Fuzzy and PSOC's congestion-reduction methods. HPSOGA reduces WSN congestion, enhancing network performance. It improves throughput, detection, energy efficiency, packet loss, and more. This study reveals that HPSOGA increases WSN performance by reducing congestion.

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