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A Review on Swarm Intelligence Based Routing Approaches

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Abstract

The principles of bio-inspired or swarm intelligence algorithms can be effectively used to achieve optimal solutions in routing for complex and dynamic wireless sensor networks or body area networks. As the name indicates, it is a field that is inspired by natural living beings like ants, bees, fishes, etc. Studies have proved that the routing protocols based on such bio-inspired methods perform better in terms of energy efficiency, reliability, adaptivity, scalability, and robustness. The general classification of routing protocols is classical-based and swarm-based routing protocols, where both the protocols were specifically categorized as data-centric, location-aware, hierarchical and network flow, and QoS aware protocols. In this paper, an evocative taxonomy and comparison of various swarm-based routing algorithms are presented. A brief discussion about the sensor network design and the major factors that influence the routing is also discussed. The comparative analysis of the selected swarm-based protocols is also done with respect to routing characteristics like query based, route selection, energy efficiency, and path selection. From the review, it is observed that the selection of a routing protocol is application dependent. This paper will be helpful to the researchers as a reference on bio-inspired algorithms for new protocol designs and also for the proper selection of routing protocols according to the type of applications.

Keywords: wireless sensor networks, routing algorithms, ant colony optimization, swarm intelligence, energy efficiency

1. Introduction

One of the most prominent technologies for the future is the networked wireless micro-sensor technology [1] because of the advancement in Micro-Electro-Mechanical Systems (MEMS) and low-power integrated electronic circuits. It includes micro-sensors with data processing, communication, and information collecting capabilities. Wireless Sensor Networks (WSNs) consist of such micro-sensor nodes, which can detect and communicate the environmental conditions with the sink. A number of research works are progressing in the area of WSN which focuses on the performance optimization of different layer protocols, algorithms for localization, test-bed development, miniaturization of sensors, low power processors, etc. The sensor network applications include sensing any location conditions and sending the data towards the sink through a radio transmitter. The constraints in WSNs like energy resources, bandwidth, and deployment of a large number of nodes are the major challenges to be met while designing a sensor network. In order to overcome these challenges, the performance of the layered protocols in the physical layer, data link layer, and network layers should be optimized. The major task, called the data routing, is handled by the network layer. It routes the data from the source nodes towards the sink node in a reliable manner. The design challenges are due to the characteristics of the network environment along with critical resource constraints, like transmission power, energy, storage, and processing capability. This necessitates powerful resource management and new routing algorithms in WSNs for reliable multi-hop communication.

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A number of innovative approaches have been proposed to enhance the performance of WSNs. The paper [2] demonstrated a Smart Home Starter Kit and analyzed commercial IoT products based on various performance metrics. The necessity for information sharing across different database platforms is discussed in [3]. The paper also demonstrated a semantic web data platform to coordinate the sharing of sensor data among the sensors and several database platforms. Generally, a basic clustering approach is used to extend the network lifetime in traditional methods. A recent innovation is proposed in [4] to increase the network lifetime, which is based on the fuzzy and spatial correlation characteristics. The correlation model divides the network virtually into clusters in order to reduce the average energy consumption and the network lifetime. In [5], an algorithm is proposed to detect and mitigate the byzantine attacks. These attacks disturb the communication between the nodes which ends up in the wastage of the network resource. Nowadays, the WSN applications are growing fast with the innovation of technologies like IoT. A new MQ telemetry transport protocol is designed in [6], to overcome the limitations of Hypertext Transfer Protocol (HTTP) in the Internet of Things (IoT). It improves the efficiency and controls the required overhead for communication. New innovations are emerging in the field of Vehicular Ad Hoc Networks for fast information collection in vehicles. The paper [7] discusses a novel routing scheme which is proactive and passive one. It reduces the traffic flow and the cost of communicating the urgent data between the vehicles.

The objective of a routing algorithm is to determine a group of forwarding nodes between a source and a destination. Based on the complexity of computation and the methods in which data are forwarded towards the sink, the routing algorithms are classified as classical and swarm intelligence based. Another classification is according to the selection of the data path, where the routing protocols are classified as proactive, reactive and hybrid [8]. In general, the routing in WSNs is categorized as data-centric, location-aware, hierarchical, and network flow and QoS aware protocols under classical and swarm Intelligence protocols.

Classical routing protocols are conventional routing mechanisms used by a sensor node or a sink node. In addition to its wide acceptance in WSN, there are a number of limitations and issues to be considered for real-time applications [9].

Swarm intelligence based routing protocols are based on the collective behavior of social insects or species, where they find a solution for distributed problems without any centralized control or coordination. An illustrative example is the ant colony mechanism [9].

Proactive routing protocols compute the routes prior to their need and are stored in a routing table in every sensor node. It also carries information about routes to each neighboring node. It has some limitations like high settling time and limited scalability[8].

Reactive routing protocols find the routes when they require. The routing overheads are reduced in these protocols, unlike proactive protocols, but the delay is more because it computes the path whenever it is required [8].

Hybrid routing protocols use both proactive and reactive protocol characteristics. A node takes a proactive feature within a given number of hops and reactive features to the remaining number of hops [8].

Based on the way in which data is sent to the destination, classical and swarm intelligence protocols can be divided into classical based data-centric, location-based, hierarchical, network flow and Quality of Service (QoS) aware protocols, and swarm intelligence as well. The examples of classical-based protocols are Flooding and Gossiping (F&G) [10], Direct Diffusion(DD) [11], Geographic Adaptive Fidelity (GAF) [12], Low Energy Adaptive Clustering Hierarchy (LEACH) [13-14], Stateless Protocol for real-time communication in sensor networks (SPEED) [15] etc.

The first swarm-based routing algorithms were specially designed for wired networks which date back to late'90s. Some of the initial protocols were Ant-based control [16], AntNet algorithms for circuit-switched telephone networks, and Internet Protocol (IP) networks respectively [17]. Slowly, these swarm-based optimization concepts were introduced to wireless networks. Some of the classical routing algorithms along with the information routing in WSNs are surveyed in [18]. The authors [19] surveyed papers on different routing protocols, which are limited to classical routing and they mainly focused on conventional routing techniques. The first survey with respect to the swarm intelligence based routing protocols along with the application and simulations, which are presented in [20]. Zengin and Tuncel [21] also performed a survey on most of the swarm-based routing protocols, but they left behind some and also not compared the protocols based on their performance and the area of applications. Gui et al. [22] also presented a survey based on swarm intelligence with promising meta-heuristics. Particle swarm optimization techniques are popularly used to elucidate various engineering issues in domains like wireless sensor networks, power systems, image segmentation, etc. The paper [23] proposed ant bee colony optimization methods to propose adaptive finite and infinite impulse response filters. An artificial Bee colony algorithm is analyzed in [24] to build a fault-tolerant routing model. The model maximizes the network lifetime, robustness, and reliability of the network.

The survey on the recent swarm-based routing algorithms is discussed and analyzed in [25-27]. A comparative survey is performed in [28] between AODV, DSDV, DSR, and ACO routing protocols. The multicast routing techniques based on swarm intelligence is critically reviewed in [29]. It also suggested hybrid techniques for enhanced performance of sensor network routing. In [30], a recent review of classical and swarm intelligence based algorithms is discussed along with its applications for IoT systems.

The remaining chapter is organized as follows: Section 2 briefly discusses the WSN design and its factors that affect the routing of sensor nodes. A brief explanation and classification of swarm intelligence based routing protocols is given in section 3. Section 4 explains the result analysis and the discussion of various swarm-based protocols. Finally, Section 5 concludes the paper.

2. WSN Routing Challenges

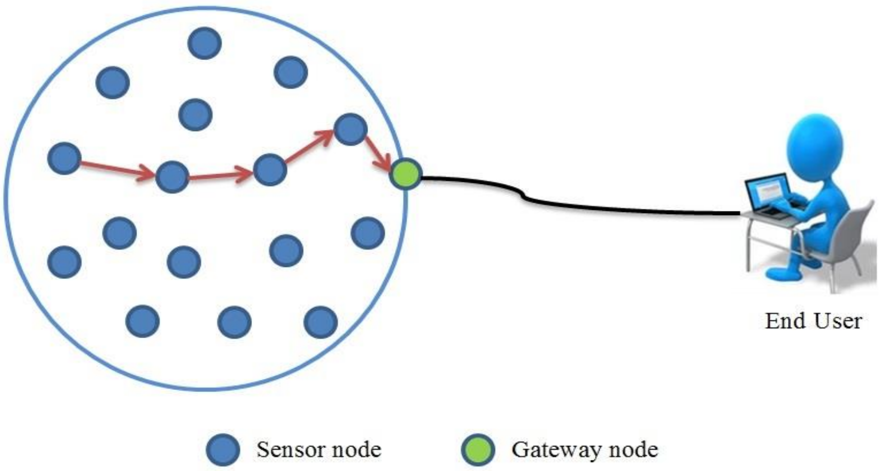

Fig. 1 An example of a wireless sensor network

WSNs include a number of compact, computational devices (nodes), which can measure environmental conditions or some other parameters according to different applications. The measured data are forwarded to a central server or a user for further processing. After the data is being collected, it has to be routed through its adjacent sensor nodes before reaching its destination, especially for multi-hop communication. Fig.1 shows a simple WSN network with sensor nodes and a gateway node. For each scenario, the operating environment is often different and dynamic which poses some distinctive challenges in the development and deployment of sensor networks [31]. The new design methods should overcome the issues like energy consumption, deployment of nodes and sensor location, dynamic network, restricted storage and processing capabilities, data aggregation and gathering, latency, scalability, fault tolerance, etc.

Energy consumption: All the nodes have limited energy capacity since they are battery powered [32]. The routing process in any network is substantially dependent on energy consideration. Hence the routing design should be energy efficient to improve the node lifespan without much performance degradation of the network.

Deployment of nodes and sensor location: The deployment of nodes is usually random in nature and application dependent. The sensor nodes create a network in an extemporary manner, hence the routing mechanism is very important to establish better routing paths between the nodes. Similarly, the sensor location is a great challenge in the initial period of route discovery, where the designed protocols assumed that sensors are provided with Global Positioning System (GPS) or equivalent techniques as given in [33].

Dynamic Network: Even though all the nodes including the sink are expected to be stationary in almost all the applications, the system should support the mobile sink in the networks. Therefore, the stability of data is to be considered in addition to the other challenges like energy consumption, latency, bandwidth utilization [34] etc.

Storage and processing capabilities: The nodes have restricted storage and processing capabilities which comes under the hardware resource constraints. These constraints may lead to a number of challenges in the sensor network. Hence, they have to be considered while designing new routing methods [35].

Data aggregation and gathering: These processes are very essential in sensor routing techniques. If the nodes produce redundant data, the same packets can be grouped for reducing the number of transmissions [36].

Latency: It is the round trip or one-way delay of packets transmitting from the source node to sink node and sink node to source node or only in one direction. Multi-hop transmission and data aggregation can affect the end-to-end delay [32].

Scalability: A sensor network includes a huge number of sensor nodes; hence, the routing protocol designed must be able to handle a number of events among nodes [37].

Fault tolerance: If any node fails, it is expected that the chances of performance degradation should be less. That means the routing algorithm should be able to establish new routes towards the sink [38].

By considering the above factors new routing protocols are developed for WSNs and Wireless body area networks (WBANs) are a subclass of WSN, where sensor nodes are placed within or on the human body to monitor the physiological activities continuously. The routing protocols that are designed for a WSN cannot be used for WBAN as there are various differences between the two networks. A survey of WBAN routing techniques has been summarized in [39].

3. Swarm Intelligence Based Routing Protocols

Social insect communities lack any organizational structure, but they are able to coordinate themselves to reach a common goal. This is due to some behavioral rules that they follow that are adaptive, flexible and resilient. These features are similar in the context to the features of wireless sensor networks. The biological network has a progressive motivation to cooperate, but the sensor network needs some external mechanisms for the same [40]. The self-organization of social insects depends on five parameters like positive feedback, negative feedback, randomness, multiple interactions and stigmergy [41]. Such coordination is called swarm intelligence. In short, it is a novel field that designs algorithms influenced by the collective behavior of biological organisms [17]. In the sensor networks, it refers to the cumulative behavior of sensor nodes that self-organize and coordinate according to the principles of ant colonies, particle swarm optimization, and honey bees as quoted in [42-43]. Swarm-based protocols can also be classified as ant-based, bee-based and slime-based protocols.

Table 1 Taxonomy of Swarm-based routing protocols

Type	Examples
Data Centric	Pheromone based energy aware directed diffusion (PEADD) [44], Comprehensive routing protocol (CRP) [45].
Location based	Sensor driven and cost aware ant routing (SC) [46]. Hybrid model using fuzzy logic and extreme learning machine with vector particle swarm optimization (HVP-FELM) [47]
Hierarchical	Self-organizing data gathering scheme(SDG) [48], Energy balanced ant based routing protocol(EBAB) [49], Adaptive clustering for energy efficient WSN based on ACO (ACO-C) [50], Ant colony clustering algorithm (ACALEACH) [51], Multipath routing based on ant colony system (MACS) [52] Data gathering communication (AntChain) [53], Probabilistic, zonal and swarm inspired system for wildfire detection (PZSWiD) [54], Ant colony based multipath routing algorithm (ACMRA) [55], Ant colony multicast trees (ACMT) [56], Ant colony optimization based location aware routing (ACLR) [57], Multi-sink swarm based routing protocol (MSRP) [58], Jumping ant routing algorithm (JARA) [59], An ant colony optimization based load balancing routing algorithm (ACOLBR) [60], Particle swarm optimization approach (PSO) [61], Differential evolution with multi objective bee swam optimization (MOBSO-E) [62], LEACH-SF [63], Bio-inspired self-aware fault-tolerant routing protocol (BISFTRP) [64], Energy efficient PSO based routing algorithm with Mobile Sink support (EPMS) [65] Beeswarm[66], Communitty-Based Routing with Ant Colony Optimization (CB-RACO) [67], Enhanced Clustering Ant Colony Routing Modified (ECACR-M) [68], FireWorks Algorithm with Adaptive Transfer Function (FWA-ATF) [69].
Network flow and QoS aware	Energy efficient ant based routing (EEABR) [70], Flooded forward ant routing (FF) [46], Flooded piggyback ant routing (FP) [46], Energy delay ant based routing (E-D ANTS) [71], Ant colony based reinforcement learning algorithm (AR and IAR) [72], A bee-inspired power aware routing (Beesensor) [73], A bio-inspired power efficient routing scheme (iACO) [74], ACO based quality of service routing (ACO-QoSR) [75], Ant colony based many-to-one sensory data routing (MO-IAR) [72], Ant aggregation [76], An ant based service aware routing algorithm (ASAR) [77], Basic ant based routing for WSN (BABR) [78], Ant colony based energy aware multipath routing algorithm (ACO-EAMRA) [79], Energy efficient ACO based QoS routing (EAQR) [51], An adaptive QoS and energy aware routing algorithm (IACR) [80], Quality of service based distance vector routing protocol (QDV) [81], Ant based routing for wireless multimedia sensor networks (AntSensNet) [82], Teaching-Learning Based Optimization (TLBO)[83], Artificial Fish Swarm Algorithm (AFSA) [84].

A swarm-based routing protocol is explained in [17], which is based on the communication between the ants using a chemical substance called pheromones. The ant's deposits pheromones on the walking paths in search of food. The other ants can reach the food by sensing the pheromones left by the ants. This mechanism inspired the technique called ant colony optimization. Like classical routing, the general classification of swarm-based routing is swarm-based data-centric routing, swarm-based location-aware routing, swarm-based hierarchical, swarm-based network flow, and QoS aware protocols as shown in Table 1. From Table 1, it is observed that recent research is focused on hierarchical protocols when compared to the other types. This may be due to the development of energy efficient clustering mechanisms in sensor networks.

3.1. Swarm-based data centric routing protocols

Data-centric routing uses attribute based mechanisms for multi-hop routing rather than a universal unique ID. Examples for this type of routing protocols are Pheromone-based Energy Aware Directed Diffusion (PEADD) [44] and Comprehensive Routing Protocol (CRP) [45]. PEADD depends on ant colony optimization and aims at maximizing the network lifetime by considering the high residual energy paths for data transmission. CRP is also based on an ant colony algorithm. It uses sub-optimal paths occasionally and is a good solution for route selection while it lacks some QoS metrics.

3.2. Swarm-based location aware routing protocols

Location-aware routing uses the intelligence of the node position or the location using some techniques to perform routing which is energy efficient. An example is Sensor driven and Cost aware ant routing (SC) [46]. Here, each node hoards a probability distribution function and calculates the cost of the sink from all neighbor nodes.

3.3. Swarm-based hierarchical routing protocols

Here the entire network is partitioned into smaller clusters and elect one node as the cluster head. Examples for hierarchical routing protocols are Self-organizing Data Gathering scheme (SDG) [48], Energy Balanced Ant Based routing protocol (EBAB) [49], Adaptive clustering for energy efficient WSN were based on ACO (ACO-C) [50], Ant colony clustering algorithm (ACALEACH) [51], Multi-path routing based on ant colony system (MACS) [52] etc. The list of hierarchical protocols proposed is given in Table 1. Some of the protocols consume a significant amount of energy, but some protocols like EBAB performed better when compared to LEACH [13-14]. Some of the clustering protocols use a cost function to enhance the packet delivery and network lifetime. The PSO approach extended the network life through the selection of optimal cluster heads. The protocols like ACOLBR [60] achieved exceptional in terms of latency and energy efficiency. The protocol like AntChain [53] assumed that communication between a node and the sink is direct and hence lacks the robustness of the algorithm. BeeSwarm [66] protocol includes BeeCluster, BeeSearch and BeeCarrier phases for routing the data packet in a robust manner. It is most suitable for large-scale applications. The recent FWA-ATF[69] method uses virtual clustering for routing and the simulation results show that it is an energy efficient protocol.

3.4. Based network flow and QoS aware routing protocols

This group includes the protocols that are not data-centric, hierarchical or location aware. In a few protocols, the route establishment is according to the network flow problem and in some; QoS metrics like latency are considered for route path establishment. The examples for swarm-based network flow and QoS aware routing protocols are Energy efficient ant-based routing (EEABR) [70], Flooded forward ant routing (FF) [46], Flooded piggyback ant routing (FP) [46], Energy delay ant-based routing (E-D ANTS) [71], A bee-inspired power-aware routing (Beesensor) [73] etc. The protocol EEABR, even though it is a QoS aware protocol, it lacks in QoS and enhances the delay in data delivery. FF uses flooding of ants from source nodes to the destination node. It uses a simple broadcast mechanism to route the packets, but some random delay is added. A protocol to reduce the delay is E-D ANTS where it uses a flat algorithm; hence, it cannot be used for large topologies. The list of swarm-based network flow and QoS aware routing protocols are shown in Table 1.

4. Result Analysis and Discussion of Swarm-Based Protocols

4.1. Performance analysis of different protocols

The performance analysis of the protocols EEABR, SC, FF, FP, and the Beesensor was done with respect to performance metrics like latency, throughput, energy consumption and success rate. The simulation time is 100 seconds. The number of nodes considered is 250 within the sensing area of 400x400 m^2. The data packet size is 512 bytes, and the control packet size is 25 bytes. The initial energy of sensor nodes is assumed as 100 Joules.

The Fig. 2 evinces that the FP is delivering the maximum number of packets successfully compared to SC, EEABR, FF, FP, and Beesensor. The Beesensor and EEABR have almost the same throughput, but less than the FP. It is shown that SC has the lowest performance in terms of throughput. From Fig. 3, it is observed that the latency is less and comparatively equal for the protocols like EEABR, SC, and FP. The end-to-end delay is expected to be high for FF and Beesensor. Fig. 4 shows the total energy consumed by each node with respect to the simulation time. All the protocols except the FP show a better performance in terms of energy utilization. But, the success rate for FP is the highest as shown in Fig. 5. The least success rate is for the protocol SC when compared to others. The protocol EEABR shows good stability with respect to the Beesensor.

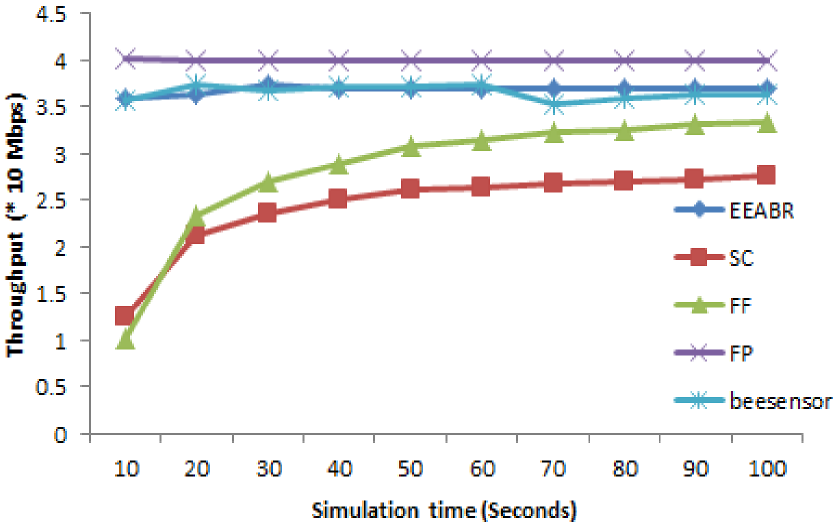

Fig. 2 Throughput vs. simulation time

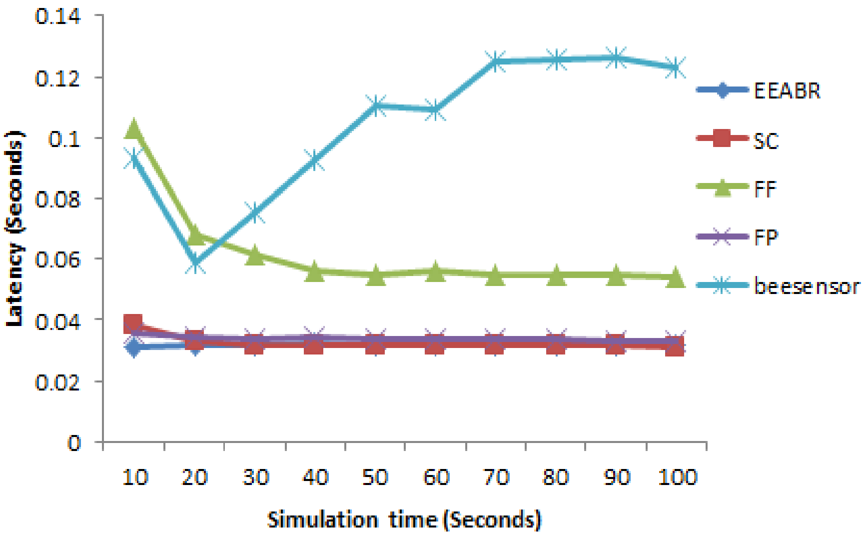

Fig. 3 Latency vs. simulation time

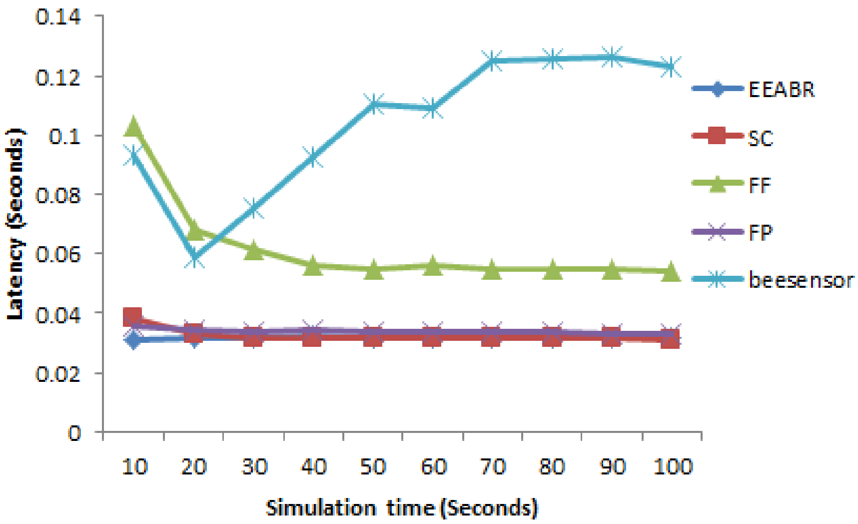

Fig. 4 Energy consumption vs. simulation time

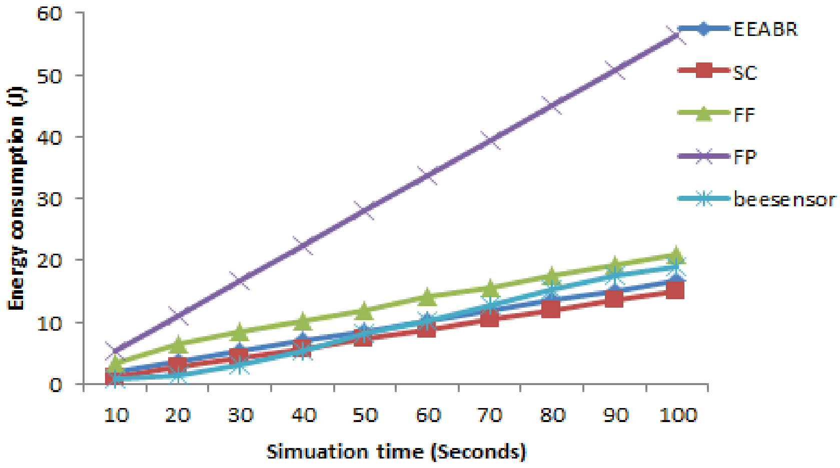

Fig. 5 Success rate vs. simulation time

4.2. State of the art

All the protocols that are proposed under swarm based optimization are compared and summarized in Table 2. The comparison is made using the metrics like route selection, energy efficiency, path selection, a goal of a protocol and query based. Swarm-based data-centric routing protocols PEADD and CRP are energy efficient algorithms, but both of them lack in terms of QoS metrics. Swarm-based location-aware protocol; SC is generally not a query based algorithm, but uses the sensing ability like ants and calculates a cost function to find the destination. It is also a hybrid protocol, which blends the strength of proactive and reactive protocols, and therefore suitable for event-based applications. There are a number of swarm-based hierarchical protocols proposed and almost all of them are energy efficient protocols. SDG is a very good protocol in terms of scalability and reliability, but it is proactive in nature. Out of all the protocols, only AntChain and PZSWiD are query-based with reactive nature.

The protocols ACLR, MSRP, JARA, and ACOLBR are the hybrid energy efficient protocols. Many protocols in the swarm based network flow and QoS aware routing algorithms promises energy utilization efficiency. But most of the protocols are proactive; hence, the number of overheads is maximum. The Beesensor is an energy efficient protocol with reactive nature and hence with the advantage of low network overhead. EEABR is an energy efficient one and suitable for periodic-based applications. Zungeru et al. [9] compared some swarm-based network flow and QoS aware routing protocols like EEABR, FF, FP, and Beesensor.

Table 2 Pros and Cons of swarm-based protocols

Routing Protocol	Pros	Cons
EEABR [70]	Highly energy efficient, better suitable when sink node is mobile	Lacks quality of service and increases delay in data packet delivery
FF [46]	Reduces the problem of wandering around the network to locate destination, can control the flooding	Very weak in terms of energy efficiency
FP [46]	High success rate when compared to FF, SC and basic ant routing	High energy consumption
Beesensor [73]	Very strong in energy efficiency, reactive protocol	Not suitable for applications where data need to be updated regularly.
BABR [78]	Increased data delivery	Less energy efficient, table driven protocol

From Table 2, it is observed that FP is highest in terms of throughput and SC is the lowest one when compared to other protocols. Applications that need 100 % packet delivery and can sacrifice energy consumption to an extent can choose the protocol FP. From the survey, it is clear that the number of classical and swarm-based routing algorithms proposed is numerous. Most of the protocols seem to be good in their properties and performance when compared to the other existing protocols. But there are shortcomings in the design of protocols such as undefined simulation environment, simulation with less number of nodes, performance degradation in dense networks, better energy efficiency but not reliable, etc. Another drawback is with the security aspect, lacking in most of the protocol designs which can be taken as a future research direction along with the QoS enhancement.

Table 3 Comparison of swarm-based routing protocols

Protocol	Goal	Route Selection	Energy efficiency	Single path(S)/ Multi path(M)	Query based
PEADD [44]	To maximize network lifetime	Reactive	High	M	Yes
CRP [45]	To reduce energy consumption by choosing the best optimal path	Proactive	Very high	M	No
SC [46]	To improve energy efficiency by sensing the destination direction and a cost function	Hybrid	High	M	No
SDG [48]	To achieve scalability and reliability in networks	Proactive	Very high	M	No
EBAB [49]	To prolong the network lifetime	Proactive	High	M	No
ACO-C [50]	To improve data delivery and network lifetime	Proactive	Very high	M	No
ACALEACH [51]	To reduce energy consumption of cluster heads	Proactive	Very high	M	No
MACS [52]	To reduce the average delay	Proactive	Medium	M	No
AntChain [53]	To aim at energy efficiency, data integrity and node lifetime	Reactive	High	S	Yes
PZSWiD [54]	To improve the speed of data propagation and reliability of the network	Reactive	Very high	M	Yes
ACMRA [55]	To reduce the energy consumption by a node	Reactive	Medium	M	No
ACMT [56]	To improve the network lifetime	Reactive	Low	M	No
ACLR [57]	To improve the data packet delivery	Hybrid	High	S	No
MSRP [58]	To make energy efficient fault tolerant networks	Hybrid	High	M	No
JARA[59]	Reduces route discovery time and route discovery overhead	Hybrid	Low	S	No
ACOLBR [60]	To reduce end-to-end delay and energy consumption	Hybrid	Medium	S	No
EEABR [70]	To improve energy efficiency of the network and average energy of the node	Proactive	Very high	M	No
FF [46]	To eliminate the problem of wandering in the network without knowing the sink, uses flooding	hybrid	Low	M	No
FP [46]	To enhance the data delivery to the sink	Hybrid	Low	M	No
E-D ANTS [71]	To reduce the time delay in fixed packet transfer	Proactive	High	M	No
AR and IAR [72]	To minimize energy consumption, latency and to improve high success rate	Proactive	High	M	No
Beesensor [73]	To make the network energy efficient	Reactive	Very high	M	No
iACO [74]	To improve the data delivery	Proactive	High	M	No
ACO-QoSR [75]	To reduce the delay and computational complexity	Reactive	High	M	No
MO-IAR [72]	To find shortest route in multi hop networks	Proactive	Medium	M	No
Ant-aggregation [76]	To enhance network life time	Proactive	High	M	No
ASAR [77]	To improve various QoS requirements in multimedia sensor networks	Proactive	High	M	No
BABR [78]	To improve the data delivery towards the sink	Proactive	Low	M	No
ACO-EAMRA [79]	To maximize energy efficiency of the network	Proactive	High	M	No
EAQR [51]	To improve QoS and balancing of energy consumption over the network	Proactive	Very high	M	No
IACR [80]	To enhance QoS and network lifetime	Proactive	High	M	Yes
QDV [81]	To maximize QoS services	Reactive	Medium	M	No
AntSensNet [82]	To reduce video distortion transmission	Hybrid	High	M	No

5. Conclusions

WSN is a fast emerging field for real-time applications which includes a large collection of resource constrained nodes. Hence, the major challenge is the design or selection of an energy efficient, reliable and robust routing protocol. From the existing works, it is observed that the major factors that influence the design of routing protocols are energy consumption, node deployment, mobile nodes, data aggregation and gathering, storage and processing capabilities of a node, latency, scalability and fault tolerance. Most of the protocols that are newly designed, considered some of these parameters to enhance network performance. The major factor considered in all research works is energy consumption. The general classification of routing protocols is classical-based and swarm-based routing protocols, where both protocols can be specifically categorized as data-centric, location-aware, hierarchical, and network flow and QoS aware protocols. The comparison of swarm-based protocols helps the researchers to choose and design an appropriate protocol or the routing mechanism according to the network application. From the result analysis, it is observed that each existing protocol could not satisfy all the QoS parameters together. For example; the protocol FP has a high packet delivery ratio and high energy consumption. Hence, it is most suitable for reliable applications with no energy constraints. Hence, the selection of a protocol should be application dependent. It is also anticipated that this paper will bring an insight to the designers to overcome the shortcomings of the existing one and to design new protocols for the much efficient, reliable, and robust sensor network.

Conflicts of Interest

The authors declare no conflict of interest.

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