An Efficient Assessment On Unmanned Aerial Vehicle Integrated With Wireless Sensor Network Applications

S.Malathy, Dr.K.Sangeetha, Dr.C.N.Vanitha

Abstract : Nowadays monitoring systems for larger areas are utilizing the wireless sensor networks (WSNs) and unmanned aerial vehicles (UAVs) integrated systems. The WSN-UAV integrated system architectures will consider many parameters such as communication and computing, networking protocols and image sensing. Since the UAVs are battery enabled devices energy efficiency have been leveraged to a maximum extent in order to prove the practical implementation of the concept. The design of suitable algorithms for efficient data processing, improving energy efficiency, reconstructing the paths, improving link quality and communication and addressing security issues has become a key research area of interdisciplinary research. The paper was focused on the concepts and applications which are utilizing UAV–WSN systems jointly and the parameters and their impact are analyzed from this point of view. The paper offers a timely review of energy efficient WSN-UAV systems in terms of topological aspects, clustering techniques, nature inspired optimization techniques, coverage and connectivity across various applications. Application references are enlisted in various domains such as agriculture, viticulture, bigdata, IoT and security. Finally, the research gaps are outlined to produce effective solutions to create a considerable economic and social impact.

Index Terms : Unmanned Aerial Vehicle (UAV), Wireless Sensor Networks (WSN), Energy Consumption, Data Collection, Routing, clustering, Security.

1 INTRODUCTION

Wireless sensor networks (WSN) have been largely utilized in various monitoring applications related to agricultural, industrial and weather forecasting. A network is designed by utilizing larger number of sensors. The data collected by all the sensory nodes will send to the sink node. Due to the limited battery power of the sensor nodes, it is mandatory to save energy consumption by optimizing other factors. The distance between the nodes, link quality, average delay, latency, packet loss, security, data update period should be considered while designing an energy efficient data collection in WSNs.The energy consumption is directly proportional to the network lifetime. Nowadays integrating Unmanned Aerial Vehicle (UAV) with WSNs provides a promising solution for energy-efficient data gathering. UAVs are similar to sink nodes (SN) in WSN. The communication links between UAV and base station can reduce transmission energy consumption. Since the UAVs are moving around, its position is changing dynamically. It is necessary to deal with trajectory path optimization issues in UAV-WSN applications.

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In this survey the techniques utilized in UAV-WSN applications are discussed and their impact on energy consumption and network lifetime is also presented. The models such store and forward, real time data transfer and hybrid model are discussed. The UAV route selection based on round robin, constant speed, variable speed, adaptable speed, hovering with unlimited service time and maximum service time are presented. The demand driven approach for route selection in UAV has also been discussed. Load balancing has been evaluated using two and four UAVs and the results are discussed. Performance analysis of various models has been presented under different network conditions, data traffic and communication environments[1]. UAV – to – UAV architecture, UAV – to – Infrastructure architecture, links between various nodes and networking layers of UAV has been discussed. The importance of middleware in UAVs, their services and heterogeneous network interface has been presented. Ease of communication in UAV based networks is important in order to reach the expected level of effectiveness in the whole network[2]. Designing efficient paths for data gathering by considering time delivery limit is presented. A hybrid heuristic approaches which combines mechanisms for solution improvement that focus on data gathering in UAVs are presented. Parameter tuning on different data sets are also illustrated [3]. The basic architecture of UAV-WSN is presented in figure 1. It consists of three layers. The bottom layer compromises of group of clusters or regions where the sensors are deployed and gathers data from the environment. The middle layer contains unmanned area of vehicles which gathers data from group of nodes from each region and sends the data to the base station. The data collected from various UAVs are sent to the base station for further processing. Here the data storage and computing technologies such as IoT, Big data, cloud may be included. This paper analyzing the performance of UAV-WSN integrated applications (Figure 2) in the following aspects. The efficient data collection based on topology, cluster based mechanisms, route optimization by combining nature inspired techniques such as particle swarm optimization (PSO) and also coverage and connectivity issues are addressed. The key management and encryption techniques are also combine to address the security issues in these applications.

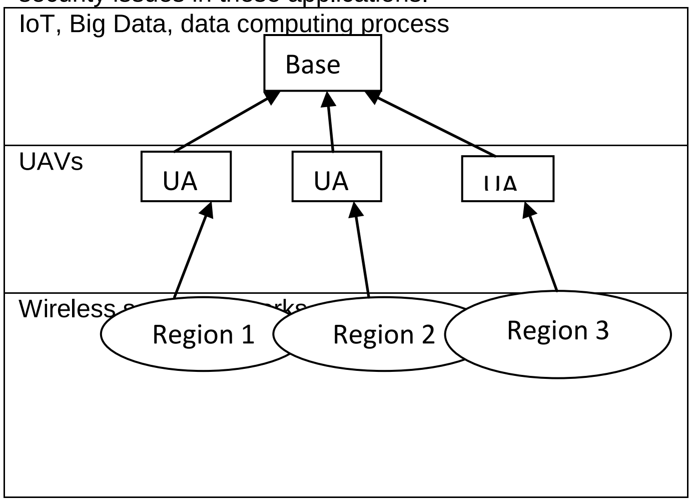

Figure 1: *Integrated Architecture of WSN-UAV*

Energy Efficient WSN - UAVs based on topology

Topology-based data aggregation protocol has been designed to improve data aggregation efficiency of WSNs. This scheme constructs the matrix by incorporating the topology information of nodes in Wireless sensor network by assigning the weight vectors to each node helps to minimize the error rate. TADA is combined with balanced minimum spanning tree (BMST), to minimize the cost of updating the matrix when the scaling of nodes takes place. The effect of link transmission failure is not considered. This scheme performs well in minimizing error rate during matrix construction and improves energy efficiency[4]. The generalized model for traversing the UAV network according to the transmission and topology information has been presented. The multi-path traversals will helps to achieve better coverage, throughput and data transfer in minimal time [5].TADA performs better in terms of energy consumption because of the smaller weight vector used in it. It proves that the increase in sparsity increases the error rates in RW and ICS whereas TADA provides a negligible error rate even though the sparsity increases. The storage requirement decrease in TADA[4]. A novel energy-efficient algorithm to achieve high system-wide energy efficiency is presented. Incorporation of Genetic Algorithm (GA) to obtain an optimal solution for large-scale WSN applications along with minimal computation time is proposed. To solve high computing complexity, a GA-based optimization protocol is developed to arrive at the best optimal solution. There are three steps in the proposed algorithm. Construct the topology of the network and calculate the route for data mule by selecting the cluster head of each cluster by implementing genetic algorithm. After determining the route data mule traversed the designated path and gathering data from each cluster. This scheme achieves lesser data update period and consumes lesser energy consumption in WSNs[6]. A nature inspired optimization technique known as Particle Swarm Optimization (PSO) is used to find the best topology which will reduce the energy consumption, error rate observed in bits, and travel time of the UAV. The PSO scheme outperforms LEACH in energy consumption and bit error rate but the travel time of the UAV remains same. Since the energy consumption is reduced, network life time has been extended while significantly increase the amount of data gathered from the UAVs[7]. To support fast data collection in large scale WSNs integrated with UAV, Regional aware Data Collection (RDDC) is proposed with three steps as follows. The region-partitioning phase in which the region is splitted into many partitions and assigning ID for each, node-scanning phase estimates the density of each node and the data-collecting phase which gathers data from all the UAVs[8].

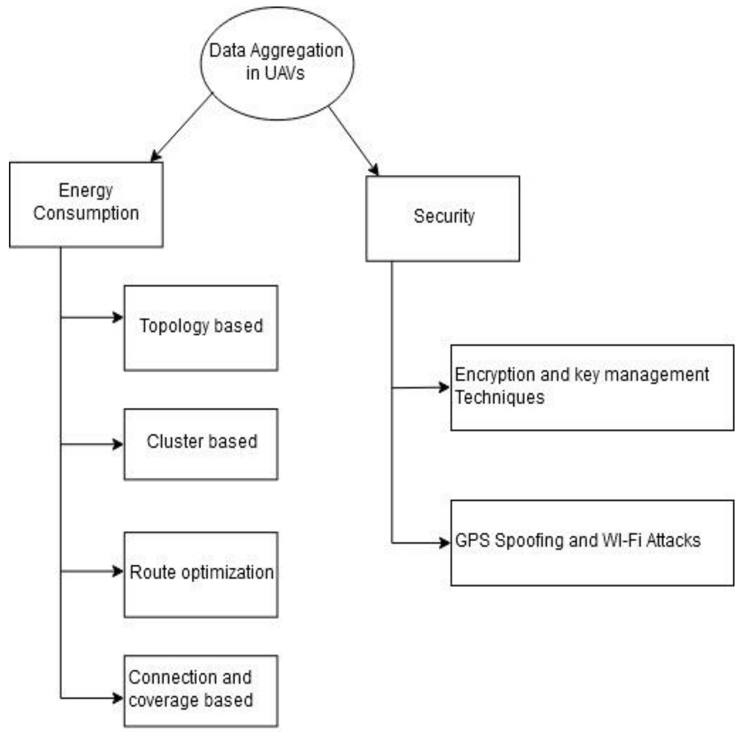

Figure 2*: Classification of WSN-UAV integrated systems*

The performance of WSN will be considerably improved if it is combined with the tree structure and clustering techniques to find the optimized paths. The use of genetic algorithms and nature inspired optimization techniques in either way will improve the energy efficiency. In table 1 the summary is presented on energy efficient WSN – UAVs based on topology.

Route optimization based Energy efficient WSN – UAVs

An energy-effective data gathering approach is designed by considering the SN's transmission policy and trajectory optimization, to minimize the energy consumption and also ensures that

Table 1: *Summary of Energy Efficient WSN - UAVs based on topology*

References	Parameter to be improved	Techniques used	Performance
[4]	Comparative sensing	Topology-aware data aggregation (TADA) protocol	Lower energy consumption, Lower data reconstruction rate in each round of data aggregation
[5]	Coverage issues	A specialized UAV mobility model designed with topological structure to determine the strategic locations to fix UAV waypoints and decide the data transmission paradigm	Better coverage, Increased throughput with lesser number of UAV's
[6]	Energy consumption, computing time for optimal path	An Energy-efficient UAV-based data aggregation protocol (computing the optimal path for data transmission)	It achieves shorter data update period and much less energy consumption in WSNs
[7]	Energy conservation	Particle Swarm Optimization (PSO) is proposed as an optimization method to find the optimal topology in order to reduce the energy consumption, Bit Error Rate (BER), and UAV travel time	Network lifetime has significantly increased
[8]	Regional density-aware data collection (RDDC) using UAV in WSN	region-partitioning, node-scanning, and data-collecting phases	obtains higher aggregate throughput and shorter delay

complete data gathering takes place from all the sensor nodes at a given time. A Dynamic Programming (DP) algorithm is combined with trajectory optimization to save the energy consumption in the UAV networks[9].To minimize the total energy consumption of all Sink nodes, UAV trajectory design and the Mean Square Error (MSE) of estimation should be less than a target threshold. An iterative algorithm based on these parameters and combining the techniques such as convex optimization and block coordinate descents are developed which gains

effectiveness in terms of total energy consumption of all sink nodes[10].

The energy consumption of the network is optimized by reducing packet collisions and also minimizing the packet loss from the back side of UAV when it is moving in forward direction. The reduced distance between senders and receivers will helps to achieve better channel quality and a significant energy saving in the network[11].Routes are adjusted dynamically based on clustering technique is proposed. The node with highest residual energy is elected as cluster head. The lifetime of the network will be extended if the nodes use optimal routes and limited update message to the limited number of head nodes. Since the cluster heads are elected in rotation basis the hotspot problem will be addressed efficiently[12]. The positions of the UAV could be determined using linearization technique and data can be collected from a subset of sensors present in the same cluster and the optimal path is evaluated to make the process of data gathering an energy-efficient one. Results show that the energy consumption is reduced to a greater extent[13]. The trajectory path is splitted into data collection intervals which is non-overlapping in nature contains one sensor each for UAV. The data collection intervals, the speed of the UAV and the transmission power of sensors are optimized together. The dynamic programming problem is used to find the flight minimization time. It is proved that optimal speed is proportional to the energy of the sensors and the distance between sensors of different clusters is inversely proportional to the uploading of data requirement[14]. The wake-up schedule of sink nodes and trajectory path are addressed jointly to minimize the energy consumption of all nodes by ensuring reliable data collection even in fading channels. While considering multi-UAVs the balance between improving the direct link and suppressing the interference link has to be addressed in future[15]. Partitioning the region based on hops routing is proposed to find the target area for each UAV. The optimal height of the UAVs can be evaluated using Air-to-Ground channel model and the optimal horizontal location is formulated using Mixed-Integer Nonlinear Programming problem which is based on the distribution of the sensors is considered. An algorithm is designed to create shortcuts between UAVs and sensor nodes which reduce the data transmission flow to a greater extent and also attains the higher throughput[7]. Reliable communication in WSNs is focused to minimize the risk of data loss when nodes present in the network without energy. A prioritization algorithm which is used to find the positions of sensors is combined with the trajectory path for collecting UAV is implemented. The key idea is when a node transmits data to several sensors, the number of control frames that would have been used for communicating each node, thereby reducing the overall energy consumption and extending the network lifetime[16]. The trajectory path or routes of UAVs (Table 2) plays a vital role in designing energy efficient UAVs. The parameters such as packet collision, packet delivery ratio, data loss should be considered to improve the overall system performance. The height of the UAVs from the ground level should be considered to define the network range.

Clustering Based WSN-UAV systems

A k-means clustering algorithm is combined with simulated annealing algorithm, in UAVs to gather sensor data. This method uses a fixed-group leader by electing using k-means clustering according to parameters such as communication quality and position. This significantly reduces the energy consumption as well as the processing time of electing a leader. It also helps to decrease the data collection complexity[17]. UAV-assisted Clustered head election framework collects information about residual energy of each sensor nodes. It makes them to elect new Cluster head by expelling the nodes which are having lowest energy from the candidate list. The minimal election period provides better security and performance[18]. By using Mobile Data Centers (MDC) data collection can be done in two different ways. Data gathering can be done either by using data mule (MULE) or through the sensors deployed in a network with mobile access point (SENMA). These schemes use multi-hop and single-hop approaches for data collection in mobile WSNs. It explains about how to determine the optimal number of clusters for minimal the energy consumption. Results show that MULE and SENMA performs well when compared with traditional LEACH schemes[19]. Maintaining connection between each sensor node for accessing them and collecting data in a lesser time are challenging tasks. The mobility patterns, cluster's count and the number of sensor nodes which could be reached has significant role in performance of the network and energy consumption. Combining clustering and the Cluster Head election algorithms with UAV mobility pattern play a crucial role in the enhancing the performance of the WSN. However the research gap remains in planning and constructing the optimal clusters based on that UAVs mobility path[20].

***Table 2**: Summary of route optimization based Energy efficient WSN - UAVs*

References	Parameter to be improved	Techniques used	Performance
[9]	Energy consumption and complete data collection based on time constraints	• Dynamic programming algorithm for optimal transmission policy • Recursive random search algorithm for preplanning trajectory trace	Significant improvement in energy consumption by ignoring either transmission design or trajectory path
[10].	Energy consumption and minimum threshold for Mean Square Error (MSE).	Joint optimization of UAV and Sensor nodes deployment based on low-complexity and systematic initialization scheme	It saves up to 90% energy consumption in all sink nodes
[11].	Reconstructing routes to find the shortest path and minimize energy consumption	Energy-Efficient Cluster-based Dynamic Routes Adjustment approach designed to minimize the routes reconstruction cost (keeping track of nearly optimal routes to the latest location of the mobile sinks)	Improvement in network lifetime is witnessed.
[12].	• Locating UAV stops • Initiating efficient data collection by finding optimal routes	3 Techniques: • Optimizing the positioning of the stops • Determining the sensor assignment stops • Finding the optimal paths using travelling salesman problem	Energy consumption is reduced to an extent
[13].	• UAV deployment • Design UAV-assisted Small World WSNs	• Region partition method • Air-to-Ground channel model • Optimal horizontal location of UAVs by MILNP method	• Reduces the data transmission delay • Attains high throughput
[14]	Optimizing UAV Flight time	• Flight time minimization • UAVs speed optimization	UAV's optimal speed is proportional to the given energy of the sensors and the inter-sensor distance, but inversely proportional to the data upload requirement.
[15].	Reliable communication in WSNs	An algorithm to minimize the risk of losing data when nodes remain without energy	The overall energy consumption has been reduced by reducing the number of control frames used for communication
[7]	To increase the efficiency of the data gathering	A scheme based on priority-based frame selection	Increases not only the network performance but also improves energy optimization
[16].	Energy consumption	Joint optimization of wake-up schedule and UAV's trajectory to minimize the energy consumption and also focusing on reliable communication.	A significant amount of network energy saving is achieved.

Compressive Data Gathering (CDG) is focused on projecting certain nodes as clusters heads and perform further transmissions using those nodes. This reduces the number of nodes involved in transmitting data to a greater extent which leads to energy saving and extended lifetime of the network. The constraints on clustering, transmission and trajectory path are taken into account[21]. For the small-scale applications data is collected from the nodes deployed in the network. For the large-scale applications, clustering technique is used with multiple data collectors to save their energy and reduce the latency in data forwarding. The results demonstrate that significant improvement on energy efficiency and average end-to-end delay has been reduced[22]. Deploying the sensor nodes in clusters plays an important role in improving the lifetime of the network. The number of clusters, communication between cluster heads, electing cluster heads based on residual energy, data transmission between the cluster heads and the sink node should be taken into account while designing an energy efficient UAVs based on clustering techniques (Table 3).

Coverage and Connection based WSN - UAVs
An Intelligent unmanned aerial vehicle anchor node (IUAN) focus on reducing the computation cost at each sensor node by implementing intelligent arc selection (IAS) algorithm. The anchor nodes estimates the location-distance messages (LDMs) for sensor nodes deployed in isolated locations and make them to reach the Control Station (CS). Further, the CS aggregates the LDMs from different cluster heads (IUANs) and determines the position of sensor nodes using IAS algorithm. This method considerably extends the lifetime of WSNs, localization coverage and localization accuracy has been improved in isolated environments[23]. The network component failure and recovery schemes are discussed. Studies exploiting the mobility of sensors to solve the coverage and connectivity issues are summarized.

The categories of coverage such as full coverage, blanket coverage and path coverage based on deployment type, mobility of nodes, dimensions such as 2D and 3D are addressed. The coverage and connectivity issues should be solved properly in order to improve the data collection efficiency[25].
A Cooperative Communication based Connectivity Recovery algorithm for UAV Networks, focus on finding better for more promising cooperative communication links. This algorithm always finishes recovery in minimal time and also achieves 100% success ratio in recovering connections during failures[26].Energy-efficient cooperative relaying scheme extends network lifetime and also guaranteeing the success rate. The energy consumption has been reduced by formulating optimal transmission schedule and bit error rates are reduced using optimization techniques[27].

Table 3: *Summary of Clustering Based WSN-UAV systems*

References	Parameter to be improved	Techniques used	Performance
[17]	• system framework • land-wireless sensor network management and • UAV mission planning strategies	• hierarchical cooperative framework • Incorporation of simulated annealing in flight trajectory	Better energy consumption, flying time,
[19]	• node energy • consumption optimal number of clusters • energy consumption	A Novel scheme for MULE and SENMA to lower the node energy consumption and reduce the funneling effect. This scheme also addresses are partitioning of the network into multiple clusters and group them prior to data collection.	• MULE Increasing the number of clusters will not reduce the node energy consumption due to the flooding problem. • SENMA A substantial amount of node energy should be expanded to transmit the data when the number of clusters is fewer.
[20].	• Effective connectivity between nodes • To gather data in a short time	selecting appropriate mobility pattern to maximize coverage and to minimize the operation time	Coverage and connectivity are enhanced
[24]	• Energy efficiency • Scalability	Reliable and Energy Efficient Data Collection Mechanism (REEDCM)	Better network performances in terms of average residual energy, average end-to- end delay, Packet Delivery Ratio (PDR) and throughput.
[21]	• Data gathering • clustering the sensors • constructing an optimized forwarding tree per cluster • gathering data based on minimized UAV trajectory distance	Projection-based Compressive Data Gathering (CDG)	Improves energy efficiency
[18].	• Security • Energy efficiency • Data collection	An UAV-assisted Cluster Head election framework • collects residual energy of nodes, • To elect new CHs by excluding the lowest energy nodes from CH candidates.	The increase in tour frequency evens the energy consumption and extends the network lifetime

Table 4: *Summary of Coverage and Connection based WSN - UAVs*

References	Parameter to be improved	Techniques used	Performance
[23].	• Network lifetime • Localization coverage and accuracy	• Intelligent unmanned aerial vehicle anchor node (IUAN), • intelligent arc selection (IAS) algorithm, • location-distance messages (LDMs)	It extends the lifetime of WSNs, localization coverage and localization accuracy in isolated environments
[25].	connectivity and coverage issues	• full coverage • blanket coverage and • path coverage • mobility of nodes in 2D and 3D	Performance are yet to be improved in Irregular sensing nodes, Energy-harvesting based sensor nodes, Geographic Surface coverage in WSNs, Underwater acoustic sensor networks
[26]	Network connectivity and recovery	utilizing cooperative communication technology to improve connectivity recovery efficiency	• Achieve connectivity recovery with less nodes and shorter distance to move and also recovery is done in less time • This method provides 100% success ratio for connectivity recovery
[27].	Lossy airborne channels and limited battery of UAVs	• Optimal transmission schedule of the UAVs is formulated • Standard optimization techniques.	The proposed suboptimal algorithm can also save energy by 50%, increase network yield by 15%, and extend network lifetime by 33.
[28].	To minimize the power consumption	A non-convex mixed-integer problem, a sub-optimal solution is obtained by applying block coordinate descent and successive convex optimization techniques.	A large amount of UAVs power is saved
[29].	Data gathering from a WSN with altitude controlled UAV	Minimum threshold for altitude is fixed to analyze the performance.	The data delivery becomes steady and the possibility of data drop out is decreased

An algorithm is proposed to minimize the total power consumption with a minimal transmission rate of sink nodes by jointly optimizing the scheduling scheme, trajectory path and power allocation techniques. The convex optimization techniques are applied iteratively to achieve performance gain[28].Data gathering in WSN integrated with UAV which attains a particular height then its speed will be constant is focused. The proposed method ensures that after reaching specific altitude speed of the UAV becomes constant, which makes the steady data delivery and the data dropping is decreased[29]. The coverage and connectivity issues are to be addressed to improve efficient data collection with less energy consumption. Once the connectivity is guaranteed with minimal data transmission time then the network lifetime will be improved. An algorithm should be developed to make the WSN network as self recovering from the connectivity issues by combining machine learning techniques.

Energy Efficient WSN - UAVs in various applications

A hybrid UAV-WSN self configuring network is designed to improve the environmental data collection in larger areas. A novel heterogeneous multi-agent scheme was proposed by adjusting trajectories and the parameters of inter and intra-line distances. This scheme helps to achieve guaranteed communication time and minimal total path length. This scheme also makes use of sensor localization and clustering method for better ground coverage to make the efficient communication between UAV and a subset of ground sensors which are acting as cluster heads. This helps to achieve better data collection. The trajectories passing near the cluster heads and also avoiding the barriers can be computed using mixed-integer based optimization technique. This helps in achieving balance between energy consumption and fast exchanging of data[30]. A network of sensors can be designed in such a way to use in agricultural fields covering vast area. A number of low-cost sensor nodes are scattered throughout the field and mobile sensor node at low costs are used for gathering data from the ground nodes. The sensor images are also obtained. The system is developed with efficient data gathering at very low cost to monitor the larger areas and helps to gather the realistic data[31]. To minimize the energy consumption and determine the locations of where to place

UAVs are two important parameters to consider while designing UAV network. The algorithm to obtain the minimum travel time of UAV is proposed which helps to collect the data quickly from the network. Since the travel time is reduced, energy consumption is also reduced which simultaneously increase the network lifetime[32]. A WSN integrated with UAVs provide an efficient solution for applications related to monitoring, because of their low cost and usage of high-resolution cameras and autonomous flying capabilities. The smart sensing network incorporated in the architecture will sense dynamic changes such as node availability and link availability, residual energy, environmental conditions and timing constraints. This could be useful in efficient data collection[33]. A UAV based Reliable and Energy Efficient Data Collection Mechanism (REEDCM) is integrated with the IoT applications. This would focus on effective data collection from unmanned areas during natural calamities. In this method the Cluster Head (CH) is selected based on three parameters such as residual energy, speed and number of nodes in the cluster. The data is gathered directly from the Cluster Heads which in turn will be transmitted to the Base Station (BS), and from the BS the data will be shared to the users via Internet. It improves the performance of the network in terms of throughput, Packet Delivery Ratio (PDR), average residual energy and average end-to-end delay[24]. The integration of UAVs with WSN has been widely used in applications where the vast area has to be monitored i.e. agricultural crop monitoring, viticulture, forest fire detection, detecting living beings during natural disasters etc., It could be implemented in all the critical applications where the human intervention is not possible. Table 5 presents the summary of various applications where energy efficient WSN – UAVs are utilized.

Security issues in WSN-UAV systems

The security threats such as GPS spoofing, jamming and optical flow spoofing are discussed. The vulnerable attacks on unsafe communication links and the security of single node in Wi-Fi network should be addressed and secure communication links should be ensured using some effective algorithms. Privacy is important for everyone, the issues caused by UAVs need to be solved urgently. Privacy is a broad area to be addressed in order to find out the drone spying effectively in critical applications [34]. UAVs can be used to perform critical tasks in military and unmanned areas. It is mandatory to ensure security during communication..The complicated spoofing attacks on GPS and on Wi-Fi are implemented using low cost and the solutions to overcome these attacks are presented which helps to tighten the group node element security on UAVs. We have to design algorithms which provide a good balance between security measures and the network communication in UAV based applications are left for future work[35].

To design architecture of UAVs with broadband wireless technologies security is one of the technical challenges that need to be addressed for handling vulnerabilities. The various methodologies of key management and trust setup, intrusion detection and GPS spoofing attacks are presented along with the solutions. The attacks on confidentiality, integrity, authenticity are also discussed[36]. Sensor node topologies arranged in circular and square array outperforms well when compared with linear array arrangement. The results are analyzes by assuming a constant drone speed and the wind speed as zero. The proper balance between drone speed and the wind speed will have a impact on

***Table 5**: Summary of Energy Efficient WSN - UAVs in various applications*

References	Parameter to be improved	Techniques used	Performance
[30].	Communication time, minimizing total path length, optimal ground coverage	Improvement in trajectory design, sensor localization and clustering	Achieves optimized energy balance and data exchange rate is faster
[31].	Covering large distance in a shorter period of time and also gathering data from the ground nodes	UAV in agricultural monitoring system	Implementation cost of sensor network with a mobile node is very low while considering the monitoring benefits of larger fields.
[33].	Data collection with minimum energy based on optimal position and trajectory of UAVs, the minimum travel time and the minimum number of UAVs in a determined deadline	Mixed Integer Linear Programming (MILP) mathematical model	optimal performance in providing the position and optimal trajectory of UAVs, energy consumption, minimum travel time, and the number of UAVs used
[31].	• To preserve the environment by minimizing water and energy use • By lowering the chemical load in the land and • To improve the yield quality.	Remote sensing, Proximity Sensing, Geolocation	UAVs with WSN provide promising solution due to their low cost, high-resolution cameras and autonomous capabilities.
[32]	Improving energy efficiency	novel UAV-assisted data collection scheme for single and multi UAVs	It achieves better performance than the control group in terms of system-wide energy efficiency and average end-to-end delay

Table 6: *Summary of Security issues in WSN-UAV systems*

References	Parameter to be improved	Techniques used	Performance
[34]	Security and Energy efficiency	efficient hierarchical architecture for UAV network using identity-based encryption	reduce overheads and data hiding mechanism to increase confidentiality of the message
[38]	low-cost implementation of these attacks and suggest solutions to them	GPS spoofing and Wi-Fi attacks, which seem to be complicated, can be launched easily at a low cost	Use of cryptographic techniques improves the network performance
[35]	security issues in UAV	Detecting unauthorized access, malicious control, illegal connection in UAVs	Authentication improves by the techniques of secure data aggregation and group management
[36]	manage the data processing tasks of heterogeneous wireless sensor network	Prototype implementation	• Circular and square array topologies always outperform the linear array topology. • Constant drone speed is assumed and wind speed is taken as zero.
[37]	Throughput Packet Delivery Ratio (PDR)	HP-MAC which is a hybrid medium access control (MAC) protocol for data gathering in a UAV-WSN	Network performance is enhanced by minimizing PDR and increasing throughput.

overall network performance which is left as an open issue[37]. UAV are sending a beacon frame periodically to sensor nodes in order to confirm its presence, each sensor node who receives the beacon frame will intend to send a registration frame to the UAV. A second beacon frame transmits the information regarding their transmission schedule. During registration based on their priority, the time-slot scheme determines the transmission schedule of each node. It also implements CSMA/CA for further promising results[39]. Since the UAVs are employed in monitoring a vast area, the data transmission is possible via internet. An algorithm should be designed by considering privacy and public safety while transmitting the data. The network spoofing attacks, Wi-Fi attacks should be addressed in order to provide secure data transmission. The establishment of secure connection should be ensured before transmitting the data over the network to the sink node.

CONCLUSION

The integrated WSN-UAV systems have become the cheapest and effective module for precise monitoring systems in various fields such as agriculture, smart cities, military applications, unmanned areas and locating living beings during natural disasters and rescue operations. This integrated system includes multiple sensor nodes and UAVs, geographically distributed WSN for large scale applications. New concepts such as IoT, Big data, Dynamic programming, and nature inspired optimization are jointly used in WSN-UAV systems in order to achieve better energy efficiency and network lifetime. Thus we conclude that in order to increase the smartness of WSN-UAV integrated systems this may be combined with machine learning techniques which paves a way to design self configuring and self organizing systems while taking battery power as a constraint.

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