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A Survey on Data Aggregation Techniques in Wireless Sensor Networks

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Abstract

Wireless sensor networks (WSN) are self organized, low cost and low power utilizing network which senses, calculates and communicates the data. The data collection at sensor nodes consumes a lot of energy and sensor nodes have limited energy. Hence most of the data-aggregation techniques aim to prolong the lifetime of the network by minimizing power consumption and optimized data transmission. In this paper, an extensive survey of various data aggregation techniques in WSN is done by categorizing the techniques as structured, structure-free, flat and hierarchical these techniques are analyzed in terms of energy conservation, network life time, packet delivery ratio, latency and various other parameters. A comparison of these data aggregation techniques is also presented along with their advantages and issues.

1. Introduction

1.1 Wireless Sensor Network

A Wireless Sensor Network (WSN) is a combination of large amount of sensor nodes. In WSN Sensor nodes are densely deployed. Generally sensor nodes are small, inexpensive, these devices are limited in power computation capacities and memory, and they may not have global identification [1], [2]. Wireless sensor networks combine with hundreds to thousands of sensor nodes that can congregate information from an unattended position and convey the collected data to a fastidious user, as per requirement of application [3]. In Wireless Sensor Network each individual sensor node is able to sense in various modalities but has limited signal processing and communication capability [4].

Wireless sensor networks (WSNs) are being envisioned and developed for a many types of applications involving monitoring and management of the physical world in a bind less fashion normally [4]. Wireless sensor networks (WSNs) are used in environmental monitoring, warfare, child education, surveillance, micro-surgery, and agriculture [5], detecting and monitoring car thefts, managing inventory control, vehicle tracking and detection [7].

1.2 Data Aggregation in WSN

Since sensors are energy constrained, it is unproductive for all the sensors to transmit the data directly to the base station. Data generated from neighboring sensors is often redundant and highly correlated. As well, the amount of data generated in large sensor networks is frequently massive for the base station for processing. So data aggregation tries to collect the most vital data from the sensors and make it available to the sink in an energy efficient way maintaining minimum data latency [8]. The main idea of data aggregation is to combine the data coming from different sensor nodes route and provide eliminating redundancy, minimizing the number of transmissions and thus saving energy [9] [10]. By using data aggregation, we can improve the robustness and accuracy of information which is obtained by entire network. It reduces the traffic load and conserves energy of the sensors [11].

1.3 Data Aggregation Approaches in WSN

1.3.1 Tree-Based Approach

Aggregating data by constructing an aggregation tree is called tree based approach. The tree is minimum spanning tree with sink node as root and source nodes as leaves. This approach is appropriate for designing optimal aggregation techniques.

1.3.2 Cluster-Based Approach

In this approach, entire network is divided in to number of clusters. There is a cluster-head in each cluster, which is selected among cluster members. Cluster-heads do the role of aggregator which aggregate data received from cluster members locally and after that transmit it to the base station (sink).

1.3.3 Multi-path Approach

Multi-path approach is proposed to overcome the drawback of tree based approach which is the limited robustness of the system. In multi-path approach, partially aggregated data is sent to single parent node in aggregation tree. A node could send data over multiple paths in which each node can send data packets to multiple neighbors. Consequently aggregation is done in every intermediate node [11].

2. Survey Reviews

There are some survey works on aggregation in Wireless Sensor Networks. Some of the survey works are discussed below.

2.1 Secure Data Aggregation in Wireless Sensor Networks: A Survey [13]

In this survey paper the authors discussed about the secure data aggregation in wireless sensor networks. The survey is based on security issues, data confidentiality and integrity in data aggregation. The aggregation techniques are classified into two cases: hop-by-hop encrypted data aggregation and end-to-end encrypted data aggregation. The authors proposed two general frameworks for the two cases. The framework that is presented for end-to-end encrypted data aggregation has higher computation cost on the sensor nodes, on the other hand it achieves stronger security, in contrast with the framework for hop-by-hop encrypted data aggregation. It needs to work on more efficient framework while keeping high resilience and security.

2.2 Features of WSN and Data Aggregation Techniques in WSN: A Survey [14]

In this paper the authors have presented some important aspects of wireless sensor networks related to data aggregation and various techniques of data aggregation. Various simulators available in sensor networks are also discussed with its merits and demerits. In this survey it was analyzed that all techniques of data aggregation focus on optimizing important performance measures such as network lifetime, data latency, data accuracy and energy consumption.

2.3 Data Aggregation Techniques in Sensor Networks: A Survey [8]

In this survey paper, the authors have presented a complete survey of data aggregation algorithms in wireless sensor networks. The authors have analyzed on efficient organization, routing and data aggregation tree construction. They have described the basic features, advantages and disadvantages of each data aggregation algorithm. This survey finds that most of the presented works has primarily paying attention on the development of an efficient routing mechanism for data aggregation.

2.4 Privacy-Preserving Data Aggregation Protocols for Wireless Sensor Networks: A Survey [16]

In this survey, the authors made a survey of several existing privacy-preserving data aggregation (PPDA) protocols for WSNs in order to provide some insights into their current status. The authors first explored the design principles, issues and challenges for PPDA protocols. Then, they investigated diverse protocols to attain privacy-preserving data aggregation in WSNs and categorized them into two types which are homogeneous and heterogeneous protocols based on the types of data aggregators. They have presented a comprehensive comparison of the presented PPDA protocols.

2.5 Data Gathering Algorithms for Wireless Sensor Networks: A Survey [17]

In this survey work the authors discussed several application specific sensor network data gathering protocols. They have investigated common network lifetime issues in wireless sensor networks and made a widespread study to classify available data gathering techniques. They focused on two key issues, which are network lifetime and saving energy.

2.6 Secure Data Aggregation Issues in Wireless Sensor Network: A Survey [18]

In this survey work, the authors have investigated the relationship between security and data aggregation process. General security issues in WSNs have been explored in this paper. This paper presents a comprehensive review of secure data aggregation concept in wireless sensor networks. Various attacks on security of data aggregation are discussed in this survey. There are some issues with WSN security requirements that implement security for duplicate sensitive aggregation functions throughout data aggregation process.

3. Survey on Data Aggregation Techniques

In this paper, various data aggregation techniques in WSNs are classified as follows.

- Structure free data aggregation
- Structured data aggregation
- Data aggregation in Flat networks
- Hierarchical or cluster based Data aggregation.

3.1 Structure Free Data Aggregation

In structure-free approaches the data aggregation achieve by using local information. There is no any extra energy loss to build any structure in structure-free approaches [19]. In structure-free data aggregations there is no established data gathering structure, each node along with event data to testimony sends any cast RTS first for determining the next hop to the sink. Any node which receives this RTS is a next hop candidate. Structure-free solutions have the reimbursement of reduced average delay, reduced maintenance overhead, and better robustness under node failures [21]. Structure-free aggregation framework provides the flexibility to the network [20]. Structure-free aggregation does not assurance that aggregation will take place even when packets follow the similar route. The advantage of aggregation may be limited if the order of transmissions does not result in packets meeting temporally at transitional nodes. The order of transmissions may be preside over by several aspects together with interference from other flows and interference from the same flow [22].

There are some papers on structure-free data aggregations which are discussed below

M. Yeganeh *et al.* [19] have discussed about the problem related to efficiency of Data Aggregation Protocol for Wireless Sensor Networks. The authors proposed a structure-free data aggregation mechanism, RDAG, for collecting delay constrained data in WSNs. This approach combines a dynamic Real-time Data-aware Routing policy and a Judiciously Waiting policy. The first policy reflects on data types in addition to real-time decisions to choose next hop neighbor nodes with enhanced aggregation performance and increases spatial convergence for the duration of transmissions without unequivocal maintenance of a structure whereas the second policy introduces artificial delays and increases temporal convergence. RDAG is analysed in terms of aggregation gain, miss ratio, and energy efficiency. Proposed method is very suitable for conserving energy in real-time WSNs. Latency of this approach is not evaluated. It should be evaluated during the process of data aggregation. It needs to use other selection route algorithms to improve our routing structure.

S. Dietzel *et al.* [20] discussed about the problem related to variation of node density for decentralized information dissemination in vehicular networks. This variation can lead to capacity issues of the wireless channel at the time when lots of vehicles are driving or standing narrowly together. To overcome this problem the authors propose an information aggregation framework using the example of cooperative traffic congestion detection. This approach completely discards any predefined structures such as grids and any group establishment. This approach is not constrained to congestion detection but can e.g. also be used to report road conditions or fog situation. This approach works well for average speed dissemination on a highway. The performance metrics like bandwidth and communication overhead is discussed in this paper. In this approach there are some security implications that arise at that time when information from several different vehicles is aggregated to one single report.

C. M. Chao *et al.* [21] discussed about the problem related to energy used by Data Aggregation in Wireless Sensor Networks. Authors propose a structure-free and energy-balance data aggregation protocol, (SFEB). SFEB has both features, efficient data gathering and balanced energy consumption. This protocol achieves early aggregation, data aggregators are selected at the earliest possible stage. Authors also scheduled the data aggregation amongst the aggregator neighbors and recommend an energy balance mechanism. This protocol enhances data aggregation efficiency in addition to reduce energy consumption through analysis, simulation, and real system implementation. Productivity in WSNs can be improved by using proposed mechanisms. SFEB is a more stable data aggregation mechanism. Performances metrics like delay and additional overhead are discussed in this paper. In proposed protocols end-to-end delay and energy consumption is increases under low aggregation ratios that imply longer packets.

S. Dietzel *et al.* [12] discussed about the problem related to overhead, efficient and accurate aggregation in Vehicular Ad-Hoc Networks. The authors proposed a fuzzy logic based approach for structure-free aggregation in vehicular ad-hoc networks. Authors employ fuzzy reasoning to allow for aggregation decisions to be based on a flexible and extensible set of criteria. These criteria can be purpose precise and facilitate a dynamic disintegration of the road according to the applications' necessities. This approach is not limited to the particular traffic situation detection but can also be used in numerous different scenarios, like reporting of road conditions or fog situations. Performance metrics like accuracy, security and data integrity is discussed in this paper. In this approach there is an implication on security, especially data integrity and the average taken over time is still very high.

K.W Fan *et al.* [15] have discussed about the problem associated to data aggregation protocols in wireless sensor network. The author proposed two corresponding mechanisms - Data-Aware Anycast at the MAC layer and Randomized Waiting at the application layer. The authors define the standardized network load as the number of packets transmitted in the network normalized by the total quantity of information delivered to the sink. The combined DAA with RW approach can advance the normalized load by as much as 77%. RW can considerably decrease the standardized overhead in form of number of transmissions; hence, structure-free data aggregation techniques have enormous prospective for event-based applications. The performance metrics like overhead, delay and throughput are discussed in this paper. The transmission delay is not considered in this mechanism it needs to be discussed because transmission delay affects aggregation.

3.2 Structured Data Aggregation

Structured data aggregation is a type of aggregation in which the network has a definite structure. Structure based data aggregation can be classified into four parts flat network based, cluster based, tree based and grid based [22]. Structured aggregation as the dominant data gathering approach in WSNs undergoes from high level maintenance overhead in dynamic scenarios for event-based applications [19].

There are some papers related to structured data aggregations which are discussed below.

Prakash G.L. *et al.* [23] discussed about the problem related to computing and maintaining network structures for efficient data aggregation in wireless sensor networks. The authors propose an optimal routing and data aggregation scheme for wireless sensor networks. The authors proposed a scheme named Tree on DAG (ToD).This is a semi structured approach which uses Dynamic Forwarding on an unreservedly assembled structure collection of numerous shortest path trees for supporting the network scalability. This scheme locally uses a structure less technique trailed by Dynamic Forwarding on an absolutely constructed packet forwarding structure. Contiguous nodes in a graph have small stretch in one of these trees in ToD. ToD is extremely scalable and it performs near by the optimal structured approach. This approach is extremely appropriate to conserve energy and to extend the lifetime of large-scale sensor networks. Performance metrics like energy and lifetime is discussed in this paper. In this approach as aggregation ratio decreases, more packets of larger size are forwarded to the root of the aggregation tree that causes elevated contention and leads to high dropping rate.

M. Yacoab *et al.* [24] have discussed about the problem related to conventional compression techniques in wireless sensor network. The authors proposed a cost effective compressive data aggregation technique for wireless sensor networks. This technique enhances the traffic load, by using structured data aggregation scheme. In proposed technique data is gathered at some intermediary node where size of the data require to be sent is compressed by using compression technique devoid of losing any knowledge of complete data. The authors also design a technique which efficiently decreases the computation and communication costs concerned in the compressive data gathering process. In this technique compressive data gathering is used that presents a compressed sensor reading for decreasing global data traffic and share out the energy consumption consistently to extend network lifetime. This technique gets better the delivery ratio at the same time as reducing the energy and delay. The performance metrics like Average end-to-end Delay, Average Packet Delivery Ratio and Energy Consumption is discussed in this paper. The simulation is done at small scale so it needs to be analyzing this approach at large scale of nodes.

M. Yacoab *et al*. [25] discussed about the problem related to security, integrity, confidentiality of aggregation techniques in Wireless Sensor Networks. The authors propose a secure data aggregation technique in the midst of reliable nodes by key predicate test protocol for sensor network. Proposed technique concentrates some nodes as Reliable nodes (R-nodes) for monitoring the aggregation process. In this technique first a secret key is shared among base station and adjacent nodes for each node, after that an aggregation tree is build to transmit data to the base station in a hierarchical approach. The aggregator encrypts the data via secret key and forwards to a level up aggregator in aggregation tree. By enhancing broadcasting feature of R-nodes, the aggregated value provides integrity. This technique increases the packet delivery ratio by reducing the packet drops significantly. The performance is evaluated primarily, according to the metrics like Average packet delivery ratio, Energy consumption and Packet drop. This technique is simulated on very small number of node like 6 nodes, It need to be analysed this technique under large number of nodes an attacker.

A. Takeda *et al.* [26] discussed the problem related to Symbiotic computing services for Aggregating Sensor Data. The authors proposed a scalable structured p2p network which supports data aggregation. In proposed p2p network, every node forwards fractional statistical results to other nodes, and each node aggregates these partial statistical results with the purpose of calculating a complete statistical result. When the p2p network is unstable then the proposed data aggregation mechanism is accurate. Besides, mechanism calculates a value which is nearby actual value although the p2p network is unstable. The data aggregation process does not need any specific protocols in p2p network; therefore the communication cost of the conservatory mechanism is extremely low. When the p2p network is unstable, the proposed data aggregation mechanism is not so accurate.

T. Nagayama *et al*. [34] have discussed about the problem associated to data aggregation in Structural Monitoring Employing Smart Sensors. The authors proposed Model-based data aggregation technique, which is supported by both structural and network analysis. This aggregation scheme employed correlation function estimation and conserve the essential features of the data even as considerably dropping data communication. The proposed data aggregation scheme is directly applicable to structural health monitoring strategies. The performance metrics like energy efficiency, time delay and data loss are discussed in this paper. In this approach synchronization error is neglected, which should be taken in account while simulation. Reliable wireless communication is not employed for this experiment, because the averaging process accommodates data loss.

H. Anisi *et al*. [35] have discussed about the problem associated to energy efficiency of data collection in wireless sensor networks. The authors proposed energy-efficient data collection approach in wireless sensor networks. This approach employs an efficient policy to forward data toward the most excellent route. There are three factors that facilitate the nodes to select a suitable parent in term of energy in the proposed algorithm. These three factors are distance, residual energy and data correlation. The lifetime and the throughput of the network will be increased, by using proposed approach. Performance metrics like total residual energy, lifetime and throughput are discussed in this paper. It needs to analyze the performance of this paper under various attacks. The performance metrics like delay throughput should be discussed.

3.3 Data Aggregation in Flat networks

In flat network each sensor nodes have a same battery power and plays the similar type of role in a network. In this type of networks, data aggregation is done in data centric routing manner. The sink usually sends a data packet to the sensor nodes, for example, flooding. Sensors that have data matching the data packet along with transmit response data packet back to the sink in the flooding [36]. In this each aggregation methods normally node has the same role and sensor nodes cooperate with each other to perform the sensing task. Since the number of these types of node is very large, so it is not possible to allocate a global identifier to each node. Therefore, Data centric routing is used, in which the base station sends queries to assured regions and waits for data from sensors located in the preferred regions [37].

There are two diffusion techniques which are used in data aggregation in flat networks, which are following.

3.3.1 Push Diffusion

In this diffusion technique all source node are active participants and start the diffusion while the base station respond to the source node.

3.3.2 Directed Diffusion

Directed Diffusion is an energy-efficient data-aggregation protocol for a wireless sensor network. It is application sensitive paradigm; means data of the sensor is named by characteristic value. Directed diffusion is able to improve the life time of the network [36].

There are some papers related to data aggregation in flat networks, which are discussed below.

J. Kulik *et al.* [38] have discussed about the problem associated to redundant data and efficiency of wireless sensor networks. The authors proposed Sensor Protocols for Information via Negotiation (SPIN). It is a family of data dissemination protocols for wireless sensor networks. To overcome several insufficiencies in traditional dissemination approaches, SPIN uses meta-data negotiation and resource-adaptation. The authors thrashed out the details of four specific SPIN protocols, which are SPIN-PP and SPIN-EC for point-to-point networks, and SPIN-BC and SPIN-RL for broadcast networks. This protocol is able to overcome two main deficiencies which are negotiation and resource-adaptation. The performance metrics like low-energy threshold, energy-conservation and time are discussed in this paper. In SPIN-BC If a node wants to send a message and finds that the channel is presently in use, then before attempting to send the message, it must wait for the channel to become idle. Whenever a node sends out a message, all nodes within transmission range of that node must pay a price for that transmission, in terms of both time and energy this is a main disadvantage of such networks. It needs to analyze SPIN protocols in mobile wireless network models.

A. Marcucci *et al*. [39] conversed about the problem allied to Overhead Data Dissemination in Wireless Sensor Networks. The author proposed Directed Diffusion Light, a variant of the well-known protocol Directed Diffusion (DD). Directed Diffusion Light characterizes local rules to produce a sparse logical topology by which DD can be run. It decreases the costs associated to the required DD periodic flooding. It results in substantial savings in terms of exchanged control messages and energy consumption, and enhancement in network lifetime. Directed Diffusion Light can boost the network lifetime four times, halve the average energy consumption, and can reduce the control overhead to one third. Directed Diffusion Light is a plain solution that can radically advance DD performance devoid of distressing its robustness. This system has slightly higher latency (up to 18% increase).It should be reduced.

M. Chen *et al*. [40] conversed about the problem allied to energy-efficiency of differentiated directed diffusion in wireless sensor networks. The author proposed an energy-efficient differentiated directed diffusion (EDDD) that enlarged the Directed Diffusion. The EDDD presents service discrimination between real time and best effort traffic by utilizing new filters, named RT filter and BE filter. A repair mechanism is employed to recover a node/link failure fast for real time traffic. The performance metrics like packet delay jitter and energy are discussed in this paper. In this system when with Traffic Mix Ratio of RT Traffic to BE Traffic (TMR) decreases, then end to end packet delay jitter of BE traffic increases. It needs to study how to expand EDDD for the circumstances with node/sink mobility, multiple sinks.

3.4 Hierarchical or Cluster based Data Aggregation.

In cluster-based data aggregation protocols, sensor nodes are subdivided into small groups which are called clusters. There is a cluster head in each cluster. The cluster head is elected to aggregate data locally and transmit the aggregation result to base station. With the help of long range radio transmission, the cluster heads can communicate with the sink directly. On the other hand, this is rather unproductive for energy controlled sensor nodes. Therefore, cluster heads usually form a tree structure to transmit aggregated data by multi hopping through other cluster heads those results in significant energy savings [31]. Hierarchical or Cluster-based routing has advantages of scalability and efficient communications [37].

There are some types of Hierarchical or Cluster based Data Aggregation which is following.

3.4.1Cluster-Based Networks for data aggregation

In this type of data aggregation all regular sensors are capable of send data packet to a cluster head (local aggregator) that aggregates data packet from all the normal sensors of its cluster and sends the succinct summary to the base station. With the help of Cluster-Based Networks for data aggregation we save the energy of the sensors.

3.4.2 Data Aggregation in chain based network

In this type of data aggregation each sensor sends data to the adjacent neighbor node. All sensors are structured into a linear chain for data aggregation. The nodes can figure a chain by utilizing a greedy algorithm or the sink can decide the chain in a centralized manner.

3.4.3 Tree-Based Data Aggregation

In this type of aggregation all nodes are ordered in form of tree means hierarchical, by the help of midway node we can execute data aggregation process and data transmit leaf node root node. Tree based data aggregation is appropriate for applications which occupy in-network data aggregation.

3.4.4 Grid-Based Data Aggregation

In this type of aggregation a combination of sensors is allotted as data aggregators in predetermined regions of the sensor network. The sensors in a grating send the data packet straightforwardly to the aggregator of that grid. Therefore, the sensors inside a grid do not communicate with each other [36].

There are some papers related to hierarchical or cluster based data aggregation which are discussed below

T. AbuHmed *et al.* [27] discussed about the problem related to resource constraints and security for data aggregation in WSN. The authors proposed a dynamic and secure scheme for data aggregation in WSN. The proposal scheme comprises level-based key derivation, data aggregation, and a new node join phases. The proposed data aggregation scheme is secure and flexible. In this scheme the key are sheltered by secret sharing primitive such that the level key will be protected on condition that the number of compromised nodes is less than t node. This scheme assures the confidentiality property of the row and aggregated data by the help of encryption. The performance metrics discussed in this paper is communication overhead. In this protocols when the attacker compromise node near the root of the tree the then it can manipulate the aggregation result much more since the big branch of lower level nodes that can attacker controls.

M. Mozumdar *et al.* [28] have conversed about the problem related to bandwidth utilization and energy efficiency of aggregation for Cluster-based Sensor Network. The authors proposed propose an algorithm to select a cluster leader that will perform data aggregation in a partially connected sensor network. This algorithm decreases the traffic flow in the network by adaptively choosing the shortest route for packet routing to the cluster leader. The authors also explain a simulation framework for functional study of WSN applications with proposed algorithm. It reduces the energy consumption of the sensor network. It needs to address the time synchronization that is required at the start of the proposed algorithm.

W. S. Jung *et al.* [29] have addressed the problem associated to tracking of multiple mobile targets in wireless sensor networks. The authors proposed hybrid clustering based data aggregation scheme. The proposed scheme can adaptively select an appropriate clustering technique based on the status of the network, raising the data aggregation efficiency in addition to energy consumption and successful data transmission ratio. Performance metrics like latency, average energy consumption and aggregation efficiency are discussed in this paper. More accurate evaluations and research needs to be done by changing some parameters in the simulation of this approach. Implementing this algorithm on real sensor motes and using more practical parameters are essential to test this proposed scheme on real world situations.

C. Liu *et al.* [30] have conversed about the issues related to energy consumption in wireless sensor networks. The authors proposed a novel dynamic clustering and scheduling approach. This approach vigorously divides the sensors into group so that the sensors in the same group have analogous surveillance time series. The authors design an Energy Efficient Data Collection (EEDC) framework that utilizes the spatial correlation to group sensor nodes into clusters. The nodes can share the workload of data collection in the future because their future readings may be almost same. The EEDC framework can effectively save energy without losing observation fidelity. It needs to analyze the other performance metrics under this framework.

J. Guo *et al.* [32] discussed about the problem related to data aggregation scheme for wireless sensor networks. The authors proposed a cluster trisecting based data aggregation scheme for cluster-based data aggregation. In this scheme cluster was trisected and all nodes find out the located area by the help of location information. The nodes, that located in the same region and have dissimilar reading with consequent reporter, will transmit their data to aggregator. The inner cluster transmission is effectively reduced by using this scheme. This scheme lowers the communication overhead and extends the network lifetime. It needs to discuss about other performance metrics regarding this scheme.

S. Mishra *et al.* [33] have proposed a cluster based routing algorithm (FDDA). They have proposed a new data delivery protocol in large scale wireless sensor networks to solve the problem of unbalance of energy consumption among the nodes. It is an improvement of LEACH protocol. First, data is sent to one main cluster head i.e. Central Cluster Head (CCH) which sends the aggregated data to the base station directly. This approach has longer lifetime of wireless sensor network in comparison of the existing schemes. When the base station is located far from the cluster-heads, then abundance energy is consumed. Hence, the farther a cluster-head is from the BS, the quicker it exhausts the energy in comparison of nearby cluster heads. This causes inequity in the energy consumption between the nodes.

4. Evaluation Table

S No.	Author Name & Reference	Technique Used/Proposed Mechanism	Type of Aggregation	Performance Metrics	Drawbacks
1.	S. Dietzel *et al.* [12]	Fuzzy Logic Based Approach For Structure-Free Aggregation	Structure free	Accuracy, Security and Data Integrity	There is an implication on security, especially data integrity and the average taken over time is still very high.

2.	K.W Fan *et al.* [15]	Data-Aware Anycast at the MAC (DAA) Randomized Waiting (RW)	Structure free	Overhead, Delay and Throughput	The transmission delay is not considered in this mechanism it needs to be discussed because transmission delay affects aggregation.
3.	M. Yeganeh *et al.* [19]	Real-time Data Aggregation protocol (RDAG)	Structure free	Aggregation Gain, Miss Ratio, and Energy Efficiency	Latency of this approach is not evaluated. It needs to use other selection route algorithms to improve our routing structure.
4.	S. Dietzel *et al.* [20]	Information Aggregation Framework	Structure free	Bandwidth and Communication Overhead	There are some security implications in this work that arise when information from several different vehicles is aggregated to one single report.
5.	C. M. Chao *et al.* [21]	Structure-Free and Energy-Balance Data Aggregation Protocol (SFEB)	Structure free	Delay and Additional Overhead	End-to-end delay and energy consumption is increases under low aggregation ratios that imply longer packets.
6.	Prakash G.L. *et al.* [23]	Tree on DAG (ToD)	Structured	Energy and Lifetime	More packets of larger size are forwarded to the root of the aggregation tree as aggregation ratio decreases that cause elevated contention and leads to high dropping rate.
7.	M. Yacoab *et al.* [24]	Cost Effective Compressive Data Aggregation Technique	Structured	Average end-to-end Delay, Average Packet Delivery Ratio and Energy Consumption	The simulation is done at small scale so it needs to be analyzing this approach at large scale of nodes.
8.	M. Yacoab *et al.* [25]	Data aggregation technique in the midst of reliable nodes by key predicate test protocol for	Structured	Average packet delivery ratio, Energy consumption and Packet drop	It need to be analysed this technique under large number of nodes an attacker.
9.	A. Takeda *et al.* [26]	Scalable structured p2p network which supports data aggregation	Structured	Communication cost of the conservatory mechanism	When the p2p network is unstable, the proposed data aggregation mechanism is not so accurate.
10.	T. AbuHmed *et al.* [27]	Dynamic and Secure Scheme for Data Aggregation in WSN	Hierarchical or Cluster Based	Communication Overhead	Attacker can control big branch of lower level nodes when he compromise node near

					the root of the tree.
11.	M. Mozumdar *et al.* [28]	An algorithm to select a cluster leader that will perform data aggregation	Hierarchical or Cluster Based	Energy Consumption	It needs to address the time synchronization that is required at the start of the proposed algorithm.
12.	W. S. Jung *et al.* [29]	Hybrid Clustering Based Data Aggregation Scheme	Cluster Based	Latency,Average Energy Consumption and Aggregation Efficiency	More accurate evaluations and research needs to be done by changing some parameters.
13.	C. Liu *et al.* [30]	Novel dynamic clustering and scheduling Approach, Energy Efficient Data Collection (EEDC) framework	Hierarchical or Cluster Based	Energy	It needs to analyze the other performance metrics under this framework.
14.	J. Guo *et al.* [32]	Cluster Trisecting Based Data Aggregation Scheme	Cluster Based	Communication Overhead and Network Lifetime	It needs to discuss about other performance metrics regarding this scheme.
15.	S. Mishra *et al.* [33]	Cluster Based Routing Algorithm (FDDA)	Cluster Based	Energy Consumption And Lifetime	Inequity in the energy consumption between the nodes.
16.	T. Nagayama *et al.* [34]	Model-based data aggregation technique	Structured	Energy Efficiency, Time Delay and Data Loss	Reliable wireless communication is not employed for this experiment, because the averaging process accommodates data loss.
17.	H. Anisi *et al.* [35]	Energy-Efficient Data Collection Approach	Structured	Total Residual Energy, Lifetime and Throughput	It needs to analyze the performance of this paper under various attacks and performance metrics like delay, throughput should be discussed.
18.	J. Kulik *et al.* [38]	Sensor Protocols for Information via Negotiation (SPIN)	Flat Networks Data Aggregation	Energy Threshold, Energy-Conservation and Time	All nodes within transmission range of that node must pay a price for that transmission, in terms of both time and energy this is a main disadvantage of such networks
19.	A. Marcucci *et al.* [39]	Directed Diffusion Light (DDL)	Flat Networks Data Aggregation	Average Energy Consumption, and Control Overhead	This system has slightly higher latency (up to 18% increase).It should be reduced.
20.	M. Chen *et al.* [40]	Energy-Efficient Differentiated	Flat Networks Data	Packet Delay Jitter and Energy	It needs to study how to expand EDDD for the

		Directed Diffusion (EDDD)	Aggregation		circumstances with node/sink mobility, multiple sinks.

5. Conclusion

In this survey various papers on different type of aggregation has been studied. Each paper proposed a technique and has some drawbacks that need to be improved. We studied the papers in four sections according to aggregation methods.

From the analysis of structured based aggregation techniques, it is observed that the existing works discussed on small scale sensor networks. It needs to suggest a scheme to employ large scale structured based aggregation and should be scalable. There is also need of improvement in accuracy and throughput. In structure free aggregation techniques, it is required to study the effect on delay from the study of hierarchical or cluster based aggregation techniques, there is a need of improvement of in energy consumption.

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