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A Review on Cluster Based Data Aggregation Protocols in Wireless Sensor Network

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***Abstract*—** Data aggregation process plays a key function in wireless sensor networks. The overall aim of data aggregation techniques is to assemble and combine information in an energy efficient way so that the lifetime of the network can be increased. In order to increase the energy efficiency and network lifetime, many researchers have proposed in data aggregation in wireless sensor networks since 1993.This research points to systematic study of subjects and challenges in data collection in wireless sensor networks. Data aggregation areas from six aspects: type of data aggregation techniques, secure data, privacy preserving data, cluster based data, energy efficient data and maximum lifetime of data aggregation. We accomplished a systematic literature review of data aggregation in wireless sensor networks in last two decades (1993-2015).we have identified 42 primary studies relevant to the aim of this research. After investigating this study, we found that six aggregation approach in wireless sensor networks. Data collection has various algorithms on the basis of performance criteria. Data collection techniques are promising in the area of wireless sensor networks. In this paper, we study cluster based data aggregation techniques approaches in networks and describe the various approaches in hierarchical networks protocols.

***Keywords*—**Data Aggregation, Wireless Sensor Networks, Clustering, Sensor Nodes

I. INTRODUCTION

In the recent past, wireless sensor networks have been introduced to utilize in many applications. Data aggregation are broadly used to decrease computation, improve scalability, and save energy in various monitoring applications of WSN moving target tracking [1], structural health monitoring [2], wildlife habitat monitoring [3], seismic monitoring [4] , and toxic waste monitoring [5], [6]. Wireless sensor networks comprise of numerous tiny sensor nodes that are deployed in an application area to evaluate the given physical phenomenon [7], [8], [9]. Senor nodes have limited processing capabilities and limitation of low battery power. Sensor nodes cooperatively transmit their information through the network to a central gateway also called as a base station. This information is piled up at base station, get analyzed and treated according to the demands. Information gathering is set as the systematic collection of sensed information from multiple sensors to be eventually carried to the base station for handling [8]. In a manner to preserve resources and energy, data must be aggregated. A simple way of doing that is aggregating (sum, average, min, max, count) the data originating from different nodes [10]. Data aggregation techniques plays a major function in wireless sensor networks. The overall intent of data aggregation algorithms is to gather and combine information in an energy effective manner so that the lifetime of the mesh can be increased. The method of reducing information redundancy by gathering the information nearby sensor nodes is called data aggregation [11].

Recent advances in wireless sensor networks (WSNs) have led to many new promising applications including environmental monitoring, facility monitoring and military surveillance [12], [13], [14]. This applications need to handover a large volume of current, detected information from one socket of the network to another. Since sensor nodes have limited processing capabilities, battery life is most important in WSNs real- time applications. This requires the procedure of energy efficient data dissemination protocols for aggregation of the detected information [15].

The rest of the paper has been organized as follows. In section 2 we analyze search strategy comprises literature resources and search process. In section 3 we discuss the data aggregation approaches in wireless sensor networks. In section 4 we conclude the paper.

II. SEARCH STRATEGY

The search strategy comprises literature resources and search process, which are detailed one by one as follows.

A. Literature Resources

The literature resources we used to search for primary studies include four electronic databases (IEEE Xplore,

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ACM Digital library, Science Direct library and Springer library). Some other important International Journals, Books, and Thesis report from google scholar.

The search terms constructed previously were used to search for journal papers and conference papers in the four electronic databases. The search conditions were adapted to accommodate different databases, since the search engines of different database use different syntax of search strings. We conducted searches in the database by keywords, title and abstract.

We limited the search to the period of from 1 June 1996 to 1 June 2015, because the applications of data aggregation in wireless sensor networks were set out in the former 1990s [16].

B. Search and Selection Process

Data aggregation involves a complete search of all relevant authors. For this cause, we defined the search process, and divided into the following three phases

Search phase 1: Search the four electronic databases, books, thesis and other journals individually and then collect the returned papers together to from a set of candidate papers.
Selection phase 1: We extract the relevant document to our subject by applying selection criteria, parameter measures and keywords.

Search phase 2: Scan the reference list of the relevant papers to find the mostly related topics in our paper and then add them into the set [16].
The detailed search process and the number of papers identified at each phase are shown in fig.1.

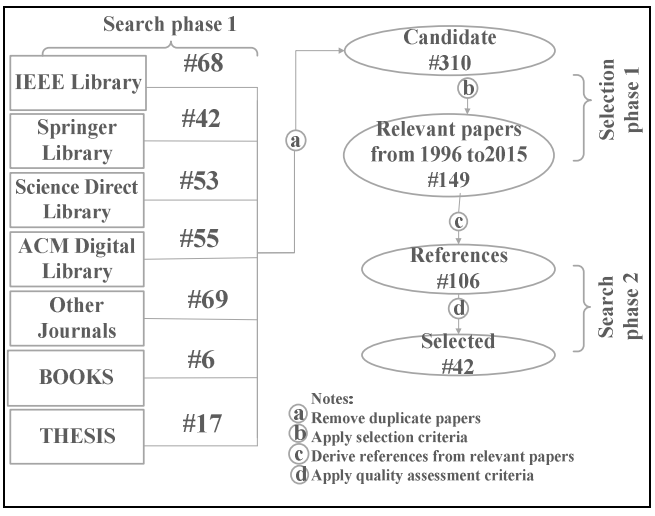

Figure 1: Search and selection process.

III. DATA AGGREGATION APPROACHES IN WIRELESS SENSOR NETWORKS

Data aggregation is a major concept in wireless sensor networks due to the strong redundancy and relationship among sensors data. Data aggregation can be known as a set of programmed approaches of merging the information that reach from various sensor nodes into a lot of meaningful data. Data aggregation solutions usually consist of three key components: aggregation path, aggregation function, and data storage [17].

Data aggregation methods are significantly blown up by network architecture as revealed in the fig. 2. Data aggregation based in networks are categorized into two. They are Flat networks and Hierarchical networks. The flat networks are further divided by depending on event-driven and query-driven, such as push diffusion, directed diffusion and pull diffusion. The hierarchical network are further classified into six parts hybrid, chain, tree, cluster, multi-path, and grid based approaches. In this paper we discuss about various cluster data aggregation protocols [18].

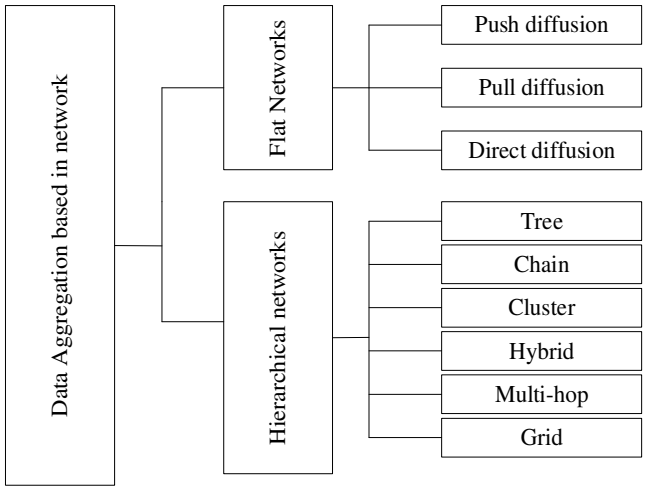

Figure 2: Classification of Data Aggregation in network.

A. Cluster Based Data Aggregation Protocols

A group sensor nodes from clusters on basis of similarity. A cluster head is formed in each cluster to collect data locally and send the aggregation result to base station. By using long rage radio transmission cluster head can directly communicate with sink. Cluster head generally forms a tree structure to send the collected information by multi-hopping over other Cluster heads which outcomes in major energy saving.

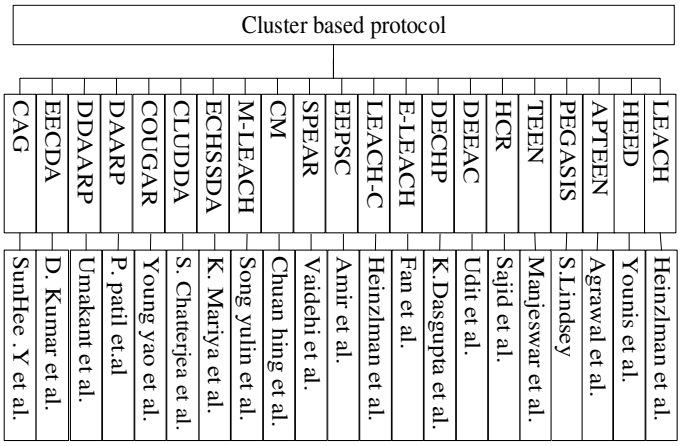

Figure 3: Cluster based protocols.

1) LEACH (Low- Energy Adaptive Clustering Hierarchy)

In 2000 Heinzelman et al [19], [20], proposed the LEACH protocol. Its major idea is to decrease the number of nodes at one hop distance from BS. LEACH protocol is primarily used for perpetual monitoring and periodic data reporting applications. Cluster head is selected randomly to transmit to the base station [19], [12]. The cluster head obtains information from all other sensors in the group, performs data collection, and transfers the aggregated information to the BS [13]. LEACH implements the full-fusion converge cast routing to prolong wireless sensor network lifetime [21]. LEACH protocol performs by two phases cluster setup phase and steady phase. Cluster setup phase performs cluster head election. Head nodes would quickly use up their partial energy. LEACH slot in randomized cycle of the high-energy cluster head place among the sensors. The aggregation of gathering information and further communication with the base station is accomplished in steady state phase [9] [20].

2) LEACH-C (LEACH-Centralized)

In 2000 Heinzelman et al [19] [20], proposed the LEACH-C protocol. A modified version of LEACH, where the central base station performs the clustering to increase energy efficiency [12]. It employs a centralized clustering algorithm to elect CH. It has same steady–state phase as LEACH but different setup phase. In the set-up stage of LEACH-C, every system transfers data about the present position by using GPS and residual energy level to BS [22] [20]. To decisive good cluster, the BS needs to corroborate that the energy load is equally spread between all the guests. For this, BS calculates the average node energy, and defines which nodes have energy below this fair, and clients have energy less than the threshold energy cannot be CHs for the present round. Once the CH and its cluster members are found, the BS announces a message to achieve the CH ID for each guest. If a CH ID is same as its own ID, the client is a CH; or else the client decides its TDMA period for data communication and goes to sleep until it's time to communicate data. LEACH uses distributed clustering algorithm and provides no warranty about the arrangement and number of CHs LEACH-C protocol can get more serious performance by dispersing the CHs throughout the network.

3) TEEN (Threshold sensitive Energy Efficient sensor Network protocol)

In 2001 Manjeshwar et al, has proposed TEEN [5] [23] an improved version of LEACH, to be ready to react to unexpected changes in the sensor versions. TEEN uses a hierarchical approach along with the use of a data-centric mechanism [13]. The closer senor nodes from cluster and process goes on the second level until BS is reached after the cluster are formed, the CH broadcasts two thresholds to all nodes in the cluster. TEEN is a reactive protocol for time serious applications where cluster head announces two values known as hard and soft threshold [22], [23]. A hard threshold allows the nodes to transmit sensor analyses only when the sensed attributes flow above the stated threshold. A soft threshold is a minor modification in the significance of a parameter which can activate a system to communicate information once more. Thus the hard threshold and the soft threshold, decreases the overall communication and provide energy efficient network [5]. The limitations of this protocol is that if the threshold are not received, the client is unable to transfer and the user won't receive any kind of data from the network.

4) APTEEN (Adaptive Periodic TEEN)

In 2002 Manjeshwar et al, has proposed APTEEN [24] an extension to TEEN. APTEEN reports both periodic data collection and quick broadcasting of time critical events. In APTEEN the threshold value is modified according to user needs and it is same for both proactive and reactive policies. APTEEN send data periodically to BS. Thresholds: consists of the Hard threshold (HT) and Soft threshold (ST) schedule: a TDMA schedule, assigning a slot to each node Count Time (CT): the maximum time period between two successive reports sent by a node. The drawback of the APTEEN to form overhead and sustaining clusters at two levels, as considerably as the difficulty connected with performing threshold based functions and in a way to handle with attributes based naming queries [22].

5) DECHP (Distributed Energy –efficient Clustering Hierarchy Protocol)

In 2002 Dasgupta et al, has proposed DECHP [25] which distributed the energy excess equally between all the node to increase the lifetime of the network and also significantly improve average energy savings. DECHP uses a location aware and energy aware neighbor CHs choice heuristic to handover attached data to the BS. DECHP uses a class

based addressing of the form <location-ID, Node-Type-ID> the location ID recognizes the geographical location using GPS, of a system that conducts identifying tasks in a particular area of the network. It is taken for granted each client knows its own location and remaining energy level. Each client within the cluster is additionally provided with a Node-Type-ID that defines the functionality of the sensor such as thermal, seismic sensing, and so on [26]. DECHP works in two key stages: setup and data communication. In the setup stages, cluster establishment and CH selection, routing tracks among CHs formation, and schedule establishment for each group are setup phase's leading events. The data communication stage involves of three key events: Data gathering, Data fusion and Data routing. DECHP offers significant performance gains for networks with large coverage areas.

6) CLUDDA (Clustered Diffusion with Dynamic Data Aggregation)

In 2003 Chatterjea et al, has proposed CLUDDA [27] has two key phases interest and data propagation. CLUDDA analyze arriving interest messages and renew interest messages to exact parts of the network. This stops nodes from having to parse through entire query definitions thus eliminating redundant processing, improving latency and reducing memory usage [27].

7) Cougar Approach

In 2003 Yao et al, has proposed The Cougar method to assign sensor networks over declarative probes [28]. Cougar method delivers partial aggregation at the child nodes for queries. Each node keeps a waiting list of child nodes sending packet to it and again same set is sent to the next hop. The query is formatted at the source node. It sends an initialization broadcast message, containing the hop count used to limit the depth of a node in the spanning route tree generated. Cougar supports in-network computation. In cougar architecture, query optimizer on sensor gateway describes the data flow in-network and computation flow in each sensor.

8) HEED (Hybrid Energy-Efficient Distributed clustering)

In 2004 Younis et al, has proposed HEED [29] for homogeneous network, which uses a hybrid method for cluster head election. The overall aim of HEED is to from efficient clusters for increasing network lifetime. Cluster-head is selected based on a mixture of a node residual energy of each node and a secondary parameter, which be subject to the node proximity to its neighbors or node degree. HEED ends in O (1) iterations, which reduce the communication cost [22]. It equally scatters cluster head overall network. HEED protocol can be used in various applications on sensor network like fault tolerance, prolonged network lifetime, scalability and load balancing [29]. The cost of a cluster head is defined as its Average of the Minimum Reachability Power (AMRP). AMRP is the average of the minimum power levels required by all nodes within the cluster range to reach the cluster head. AMRP provides an approximation of the communication cost.

9) CAG (Clustered AGgregation)

In 2005 Yoon et al, has proposed CAG [30] approach to increase current in-network aggregation mechanisms by supporting this spatial property of sensor information [5]. CAG is the first system that appreciates the semantic transmission to conserve energy, while confirming bounded approximation by supporting the spatial and temporal correlations prevalent in nature. It uses query routing and query processing to attain efficient in-network processing. By using query routing tree CAG method obtains both resulting error and energy usage [5]. CAG generates a synopsis by filtering out insignificant elements in data streams (lossy algorithm) to minimize response time, storage, computation, and communication costs. CAG exploits semantic broadcast [31] in order to reduce the communication overhead by leveraging spatial and temporal correlations. The advantage of CAG is the high precision of the approximate results.

10) CM (Clustering-based data gathering protocol with mobility)

In 2005 Liu et al, has proposed a CM protocol [32], [33] to reduce energy dissipation for information collecting with mobile sensor nodes. By utilizing the mobility CM form the cluster groups. The sensor node uses the data achieved from GPS device to guess its distance from all other CHs. This guess benefits the client to choose the cluster to which it desires to relate. Clustering-based data collecting protocol works in cycles. Each cycle has two key steps: organizing cluster and message transmission. In organizing cluster phase consists of two steps- one step is to elect the CHs and then the following step is to form clusters. This protocol extends the lifetime of network as compare to LEACH. It consider node mobility.

11) BCDCP (Base-Station Controlled Dynamic Clustering Protocol)

In 2005 Muruganathan et al, has proposed BCDCP [34] protocol, which allocates the energy dissipation equally between all sensor nodes to expand the network lifetime and normal energy savings. BCDCP is a centralized protocol in which BS is assumed to have energy and computing power in plenty. BS is assumed to know all the node locations. Nodes to have control over transmission power. BCDCP has setup and communication phase. In communication phase by using a TDMA schedule, nodes send data to cluster head and CH performs data fusion. Compressed data is routed to the base station. In the setup phase, it chooses

two most individual nodes from potential cluster heads. Device nodes are based on proximity.

12) HCR (Hierarchical Cluster-based Routing)

In 2006 Hussain has proposed HCR [35] procedure is an improvement of the LEACH protocol that is a self-organized clustering method for constant observing of the network. The HCR procedure is to produce energy-efficient cluster of erratically arranged sensor nodes and the energy-efficient clusters lasts for a extended duriation of time; the energy-efficient cluster is designed by using heuristic approaches. The BS centrally performs the cluster establishment using Genetic Algorithm (GA) to create energy efficient hierarchical clusters. In HCR, cluster management is done by a set of associates called the head-set; using the round robin method, each secondary member acts as a CH. The role of a CH is preserved for a small period called a round. A round consist of two stages, an election stage and a data transfer stage. During the election stage, the new set of clusters is formed by self - organizing of the sensor nodes, and each cluster has its own headset [36]. During the data transfer phase, CH aggregates and forwards the received message from the cluster members to a distant BS. This approach reduces the number of CH elections. For the next election, the retaining of cluster in HCR protocol results in a major quantity of development related to the LEACH protocol.

13) E-LEACH (Energy LEACH)

In 2007 Liu et al, has proposed E-LEACH [37] protocol to improve the CH selection procedure. It considers the residual energy of nodes to select which node will be CH or will not be after the first round. As like LEACH, E-LEACH is also divided into rounds and each round contain cluster formation phase and cluster steady phase. Every node has the same probability to turn into CH in first round and nodes are selected as CHs randomly. In next rounds, residual energy of nodes consider to select the CHs, because residual energy of nodes is different after each round. The nodes have high energy will become CHs rather than nodes with low energy. Simulation results show network death time for Energy-LEACH protocol longer than LEACH protocol. The results show that Energy-LEACH protocols prolong the network lifetime as compared with the commonly used LEACH protocol.

14) M-LEACH (Multi-hop Low- Energy Adaptive Clustering Hierarchy)

In 2007 Xiang et al, has proposed M-LEACH [37], [38] protocol picks the best route among the CH and the BS through other CHs and use these CHs as a relay station to convey information over through them. Frist, multi-hop communication is agreed among CHs. Then, according to the selected optimal path, these CHs convey information to the corresponding CH which is nearest to BS. Finally, this CH sends data to BS. M-LEACH protocol is almost the same as LEACH protocol, only difference is that it makes communication mode from a single hop to multi-hop between CHs and BS.

15) DEEAC (Distributed Energy Efficient Adaptive Clustering Protocol)

In 2007 Mitra has proposed DEEAC [39] an improvement over the LEACH protocol. It is a finest cluster-based procedure with the basic idea to prolong network lifetime. The proposal of procedure deliberates the information reporting rates and enduring energy of each client within the network. The area in the network having large information generation amount are well thought-out to be “hot regions”. Hotness value of a node is a parameters representing the information generation rate at that system comparative to the entire network. The DEEAC consider two further constraints for CH selection. These constraints are the left over energy of a node and the hotness of the region sensed by the node. The key role of DEEAC algorithm is to select system with large left behind energy and larger hotness values as CHs. DEEAC picks a node to be a CH dependent upon its hotness value and left behind energy. This is an expansion over stochastic method utilized in LEACH in expressions of energy efficiency. DEEAC distributive approach is further energy efficient than the centralized method. DEEAC equally allocates energy-usage between the nodes in the network by capably familiarising to the variations in the network, optimal CH selection protects a huge quantity of communication energy of sensor nodes. This prolong the lifetime of the system.

16) SPEAR (Sensor Protocol for Energy Aware Routing)

In 2007 Bhuvaneswari et al, has proposed SPEAR protocol delivers extended stability phases, a higher average throughput and longer network lifetime. SPEAR [40] use an adaptive and conceptually novel paradigm, for the election of CHs based on energy as well as spatial distribution. The protocol keeps a minimum threshold distance between any two CH leading to a uniform energy load distribution among the nodes. The protocol has two phases, namely setup and steady state. In the setup phase, the CH election and cluster formation is executed which is purely based on the energy level of nodes and implement a stack that guarantee an even scattering of CHs. The steady state phase is like as in LEACH (transfer data between CHs and BS).

17) EEPSC (Energy-Efficient Protocol with Static Clustering)

In 2008 Zahmati, has proposed EEPSC protocol [41] to remove the overhead of dynamic clustering and appoints high power sensor nodes for strong tasks. By using a hierarchical static clustering based protocol EEPSC extends the network lifetime. In EEPSC, which node has more energy forms as CH. EEPSC works in cycles and each cycle consists of three phases: set-up phase, responsible node

selection phase and steady state phase. In this protocol the cluster is established once at starting of the network by static clustering scheme. In EEPSC the cluster formation is done by the BS, broadcasting k-1 different messages with different transmission powers where k is the desired number of clusters [42] . EEPSC extends the lifetime of network and increases the overall number of messages received at BS as compare to LEACH.

18) EECDA (Energy Efficient Clustering and Data Aggregation)

In 2011 Kumar et al, has proposed EECDA mixture of energy efficient cluster based routing and data aggregation for refining the presentation in terms of lifetime and stability [9]. It is for the heterogeneous WSN. EECDA stabilize the energy depletion and extends the network lifetime by a factor of 51%, when compared with LEACH. Advantage of EECDA it increases the network performance by using some heterogeneous node in the network. Disadvantage of EECDA is the election process of CHs makes the network unstable.

19) M-EECAD (Multi hop Energy Efficient Clustering & Data Aggregation Protocol for Heterogeneous WSN)

In 2014 Surrender et al, has proposed M-EECDA [22] to support the energy depletion of the network efficiently. It is a mixture of clustering and multi-hop communication to increase energy consumption, stable region and network lifetime overall the network. To save energy in the network EECDA presents a three level architecture and sleep state for some cluster heads. M-EECDA consists of three types of sensor nodes: normal, advance and super. To turn a cluster head in a round normal node use residual energy based scheme. Advance and super nodes further act as a relay node to reduce the transmission load of a normal node cluster head when they are not clustered heads in a round.

IV. RESULTS AND DISCUSSION

In this section we discuss the overview of the selected studies and discuss the some related works also provided to support the findings.

A. Overview of selected studies

We recognized 40 studies in the area of data aggregation technique in wireless sensor networks. These papers are published during time period 1996-2015. Among them, 22% papers from IEEE library, 17% papers from Science direct, 18% papers from ACM library, 22% papers from other Journal, 14% papers from Springer library, 2% papers from books and 5% papers from reports. The percentage of study of all papers has shown in fig.4. A graph of chronically collected number of papers form 1996-2015 as shown in fig.5.

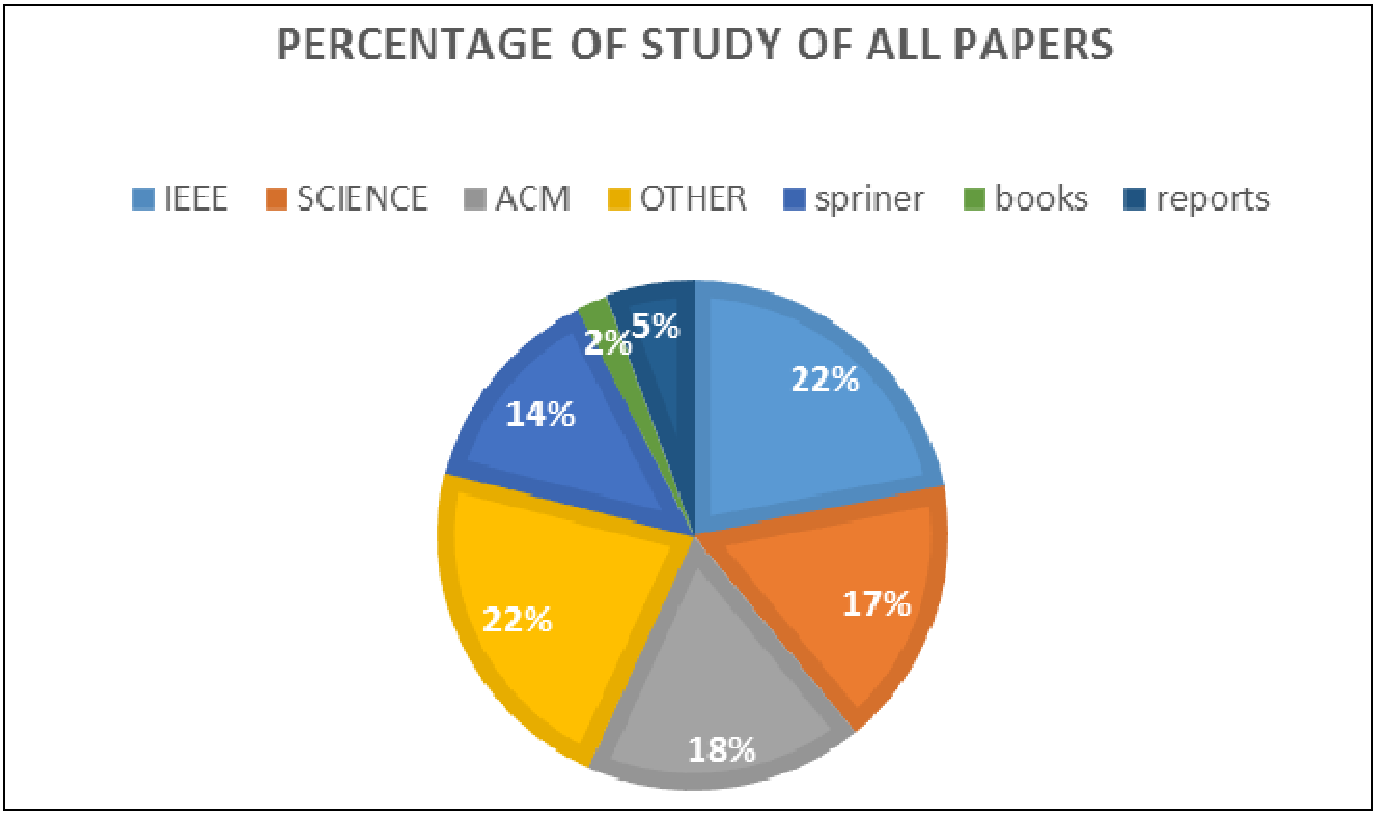

Figure 4. Percentage of study of all papers

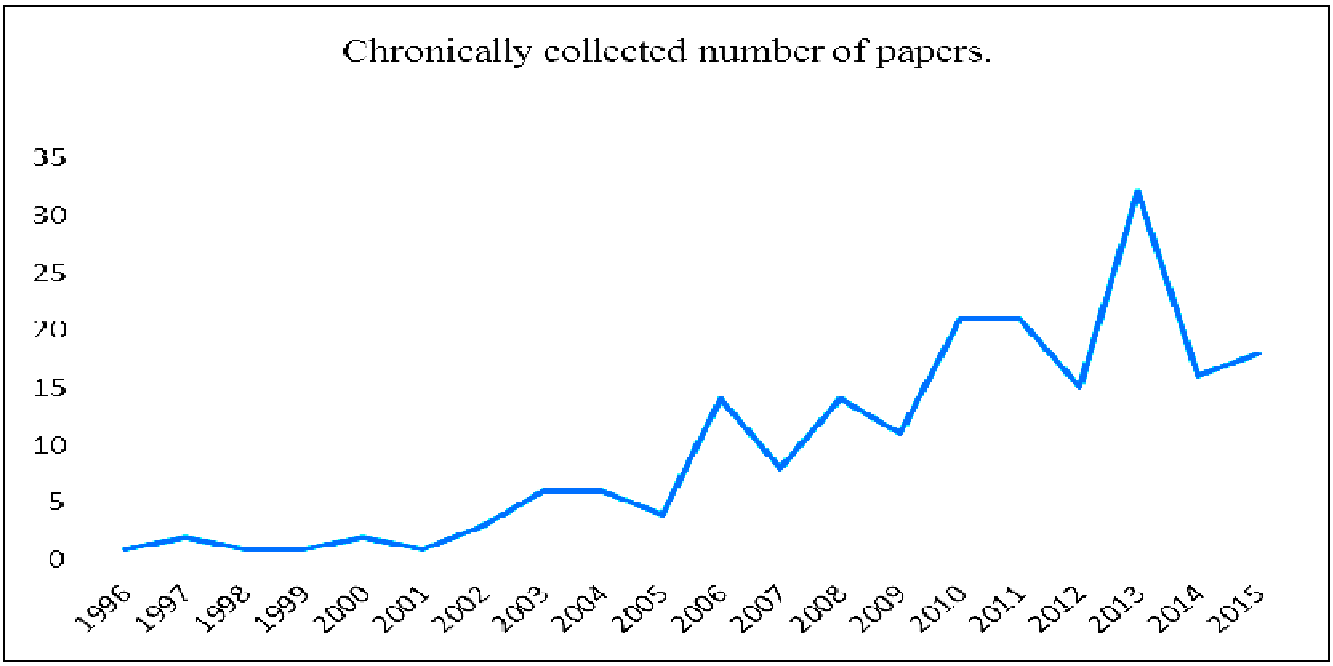

Figure 5. Chronically collected number of papers

B. Types of data aggregation techniques

From the selected studies, we identified six type of data aggregation methods that had been applied to estimate wireless sensor networks. They are classified as follows.
1. Tree, 2. Cluster, 3. Chain,

4. Hybrid, 5. Multi, 6. Grid

Among the above listed DA methods tree, and Cluster are the two most frequently used. In this paper, we had discussed various clustering protocol are used for data aggregation in wireless sensor networks. Presents only the amount of research attention that each type of Cluster data aggregation technique has received during the past two decades; Fig. 6 is plotted to further present the distribution of research attention in each publication year.

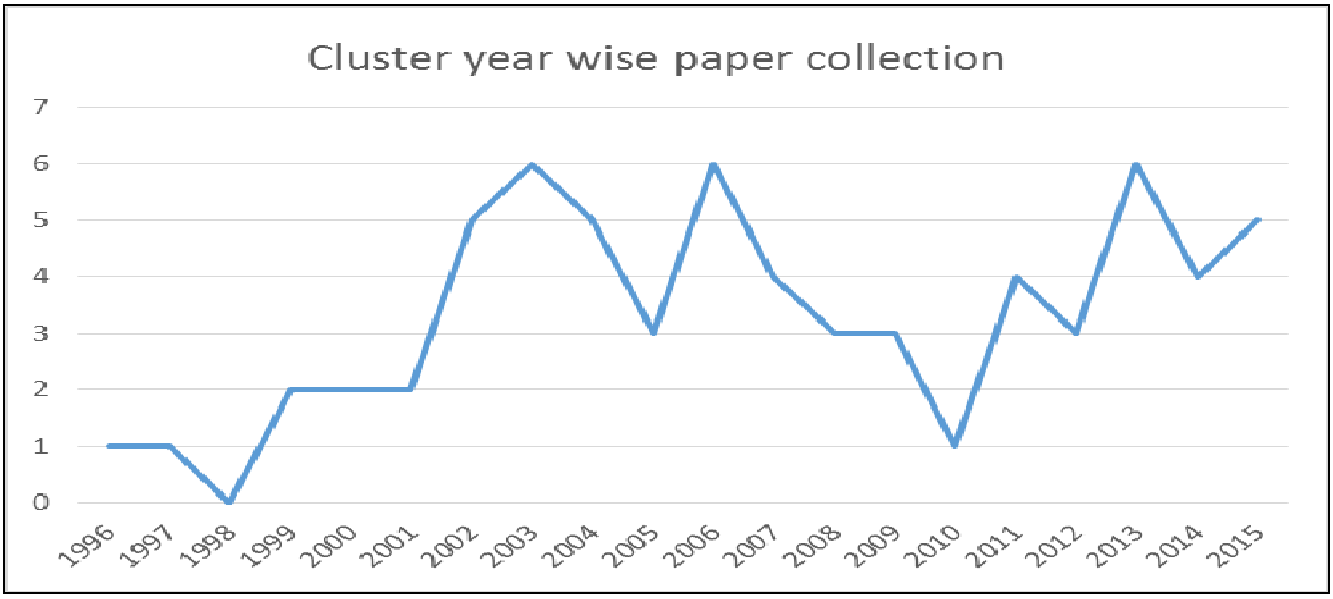

Figure 6. Cluster year wise paper collection

V. CONCLUSION

In this paper we discussed various cluster data aggregation techniques are used to achieve performance measures such as lifetime of the network, energy consumption, hop count, throughput, communication overhead and data accuracy. We accomplished a systematic literature review of data aggregation in wireless sensor networks in last two decades (1996-2015). It was identified that 42 primary studies relevant to the aim of this research. In this paper we had studied the Classification of Data Aggregation in network. We have studied, the key features, the benefits and drawbacks of cluster data aggregation protocols.

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