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A Survey on Continuous Object Tracking and Boundary Detection Schemes in IoT Assisted Wireless Sensor Networks

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ABSTRACT With the new age of data innovation, the Internet of Things (IoT) proliferation has drawn enormous thought and has applied to help applications in different fields i.e. natural assurance, military observing, and industrial applications. WSNs are the essential segment of IoT for monitoring as well as tracking. The most preeminent applications provide confinement and identification of continuous objects i.e. wildfire, toxic gas, bio synthetics concoctions, and so forth. In the case of continuous objects such as fire and toxic gases are detected to identify the boundary of damage and alert teams for rescue efforts. It is also helpful in identifying safe paths for rescue. We have investigated various existing surveys that carried out different concepts associated with continuous object tracking and find out the deficit of boundary detection of object. In order to replete the present cleft of analysis, we have inspected various current state-of-the-art works on boundary detection of a continuous object that has yet not been added to the current writing. This paper presents an extensive overview of different continuous object tracking schemes which involve energy efficiency, boundary detection, communication, data aggregation, and network structural design in literature with the aid of featuring taxonomy. We summarized, compared, and classified these schemes along with their analysis and performance. Moreover, for further evaluation mechanism, strengths and weaknesses of these schemes are presented. Finally, various state-of-the-art open research challenges are identified. Moreover, there is a need to overcome these challenges through novel and reliable arrangements by the researchers.

INDEX TERMS Boundary Detection, Continuous Object, Network life, Object tracking, WSN.

I. INTRODUCTION

WSNs are basically consisting of large number of low powered sensing devices which are capable for sensing multiple events with limited amount of resources [1]. Remotely areas which are not investigated up till now due to its hazardous nature and inaccessible places WSN is found to be most effectual solution [2]. A novel paradigm Internet-of-Things (IoT) [3] devices are emerging to build up the cost effective wireless sensor nodes that are connected with internet in sensing and monitoring processes. With the rapid and progressive technological development, IoT assisted WSN are widely applicable in environmental protection, industrial applications, military, habitat, agriculture sector, forest fire detection, health monitoring, seismic disturbance, volcanoes, earthquakes after shots stress detection, smart buildings, and predictive maintenance, etc. The WSN is the basic component of the Internet of Things. The combination of IoT and WSN tends to edge technology [4].

The smart sensing devices are densely deployed in a target area for surveillance of an event of concern connected by wireless media [5]. These sensors have the ability to sense data processed and exchange the data with neighbor(s), they also responsible for report sensed data back to the sink or base station (BS). Sink Node (SN) has capability to widely communicate with outside world i.e. Laptop. Recently, sensor node deployment plays considerable roles in military surveillance, traffic control, environmental monitoring, gas leakage detection, oil spills, battlefield and intruder tracking [6]. For tracking and monitoring the physical or environmental conditions, (i.e. temperature, movement, sound, vibration and pressure) sensor nodes are distributed in the target area. Sensors have power scarcity issue, derived by limitations of battery size and capacity, which have a great influence on extending the network life in terms of sensor energy utilization [7]. Therefore, it is considered as a significant issue for prolonging the network life and for many applications of target tracking [8] [9] [10].

The continuous object scatters over a large area i.e., wild fire, agricultural infections [11], toxic gas leakage and oil spill [12] [13] [14] in industrial applications. Continuous objects change their shape and size dynamically. The tracking mechanism initially detects and estimates object position and then continuously monitors it [15]. However, sensor nodes are low powered with limited sensing capabilities and there is a need to enhance the energy efficiency, network life time [16] and object monitoring and tracking [17]. Efficient report generation is an essential requirement for tracking the location of object in real time. In individual object tracking, the main concern is about how to predict and track the next location of the target. Secondly, what procedure should be adopted to notify the immediate tasking nodes in a huge area [18].

Object tracking and boundary detection is a challenging problem due to its speedy movement over time, increase in size, change in shape and split into multiple smaller continuous objects [19], [20]. Although, boundary detection is an efficient way to send data to sink as compared to normal detection phenomena in which number of sensing nodes send data to the sink and enhances the data traffic and communication cost. However, reliability of data is an essential requirement while estimating the boundary but failure of boundary nodes reduces the reliability and accuracy of boundary detection [21] [22].

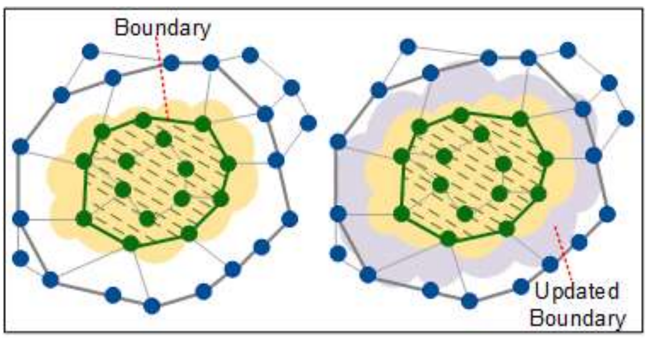

FIGURE 1. (a) Boundary detection of continuous objects for leakage area during a specific time span.

Existing surveys explore the target tracking, network architecture strategy, node deployment, energy efficiency, gas diffusion models and different tracking techniques for continuous object. These surveys lack in presenting the object detection and boundary detection schemes. It is most significant concept for continuous objects detection that has not surveyed yet. To fill this gap, we investigate various current state-of-the-art schemes which consider both scenarios of object detection and boundary detection. The main contributions of this work are explored as follows;

1) We conducted a comprehensive study on existing surveys conducted on the topic. Table 1 presents a summary to highlight the need for this survey.
2) We explored different continuous object and boundary detection schemes and presented review of these schemes in literature. A taxonomy is presented to classify the recent studies in literature.
3) Next, we conduct an analytical review of different studies that are discussed in literature. We also discuss the comparative review of these schemes.
4) Finally, we categorize open research issues and challenges that should be resolved through novel and dependable solutions by the researchers.

The rest of the paper is organized as following Section II, we have included taxonomy of continuous object tracking. Section III, provides analysis of the schemes and comparative discussion to highlight strengths and weakness of associated schemes. In section IV, we discussed recent developments and open research issues and challenges and at the last in Section V, we conclude our work.

II. LITERATURE REVIEW

This section presents taxonomy for different object tracking schemes as shown in Figure 2. These schemes further categorize into individual and continuous objects but we are focusing on continuous objects. We also categorize these schemes under three sections like object tracking schemes, boundary detection schemes and both object tracking and boundary detection schemes.

A. CONTINUOUS OBJECT TRACKING SCHEMES

C. Zhong and M. Worboys provided a dynamic convoy tree-based collaboration (DCTC) approach for mobile target detection and tracking. This scheme constructed a tree base structure (convoy tree). It contains the sensor nodes that are in the region of mobile target. As the target object moves convoy tree is constructed dynamically for adding and removing sensor nodes in respected region. When a phenomenon region is detected by the nearby sensors nodes, these sensors cooperate with others sensors nodes for root node selection and constructed a convoy tree. Root node gathers data about boundary detection from others sensors and based on that information it used some algorithm to acquire the accurate information of target. Communication overhead occurs when the sensors collaborate with each other for root selection and sharing information. Most of the time this technique focuses on individual object tracking such as vehicles[27], animals and humans [28]. L. Liu et al, introduces a continuous object boundary detection protocol to effectively detect the faulty nodes with a minimum number of boundary tracking nodes [29]. J. H. Kim et al. presented the energy efficient Detection and Monitoring for Continuous Objects (DEMOCO) approach, it selected small number of boundary nodes, to minimize the message size transferred from boundary nodes to the SN, this algorithm use

TABLE 1. Summary of Existing Surveys focused on COT based Schemes

Focused Topic of COT	Description
A survey on target tracking techniques in WSN	K. Ramya, et al. [9] presented a survey in which examines some of the target tracking techniques and presented the advantages, problems and promising improvements of each technique during analysis. It also introduces, compares and sum up some of the currently used algorithms for target tracking along with comparison of their performance and evaluation in sensor networks.
A comparative study on gas leakage source detection and boundary tracking	Lei Seu, et al. [22] presented a survey that provides a comprehensive study about existing and newly establish work on gas leakage detection and tracking in WSNs and also enhanced the various well known features of gas diffusion models based on accurate boundary estimation in localization and tracking algorithms.
A review on energy efficiency in collaborative target tracking	O. Demigha, et al. [18] presented a survey in which advance target tracking schemes are discussed to conserve the network energy efficiently and maintaining the data accuracy. Also provides the classification of schemes and their comparison that are used to resolve the energy consumption issue by in between interaction of communication and sensing layer.
Comparative study on target tracking schemes in wireless sensor networks	Asmaa et al. [23] explore target tracking approaches and analyze against multiple metrics. Schemes are based on target tracking accuracy and energy maintenance. Although, it highlights challenges that effects the performance of the target tracking schemes. However, these challenges are not highlighted clearly.
Comprehensive survey on network localization, tracking and navigation technologies	Christos et al. [24] discussed cellular localization systems and solutions based on WLAN. Elaborated mobility estimation schemes only those can applicable in cellular networks. Tracking and navigation applications are mapped into a physical space scenario. It also point out the availability, scalability, security and privacy concerns in the location oriented schemes.
A review on object tracking sensor networks in smart cities	Mohammed et al. [25] presented the important characteristics of object tracking sensor networks by elaborating multiple algorithms of monitoring and tracking schemes in smart city scenario. Elaborate the technical challenges based on tracking of object, prediction of location and recovery. The limitations and significant opportunities are not properly discussed.
Comparative study on mobile object tracking in WSN	Marjan et al. [26] investigated the schemes based on mobile object tracking in wireless sensor networks using network centric approach and identify tracking issues and introduces design constraints for the efficient object tracking. Multiple open research directions are discussed for future research studies but challenges are not properly discussed for object tracking sensor networks.

RN among BN for data transmission. If a node has the different reading from the previous reading, then that node become “changed value node (CVN)” and broadcasts COZ message to its one-hop neighbors. When BN received a COZ message, it gets shorter back-off time and wake up early. It banned the other BNs to become RNs through control message. To lessen the message size, RN sends only the nearest neighbor’s node ID among various neighbors of sink which carry unique values. For boundary identification this approach exchanges massive messages. DEMOCO approach is modified to examine the sensing range for Boundary Accuracy of continuous object tracking [30].

T. R. Sheltami et al. presented a Continuous Objects Detection and Tracking (CODAT) Algorithm for detecting and tracking the expanded and shrinking phenomenon. It also monitors holes inside the phenomenon. CODAT algorithm is hybrid of COBOM and DEMOCO algorithms. Through these algorithms energy consumption is gained by the help of few nodes selection among large number boundary nodes for reporting, but the boundary accuracy is compromised. CODAT removes the deficiency of boundary accuracy and used the average report data size by RNs for forwarding to sink. In this approach when a sensor node detected the phenomenon it broadcasts PCM after checking the current PDS status that not matched with previous reading. When other sensor node receives PCM, it matches its own PDS with it. If it comes to know that PDS is same then it will discard the PCM. But in the case of at least one PDS is different, and then this node becomes a BN. After that it counts the number of PCMs different waiting time and used this information for making RN. RN reports the boundary information with recent tags to the SN. During the expansion of continuous object only the nodes in the outer region of the phenomenon become BN. Correspondingly, in shrinking of object BN will be those nodes that are inside the region. This reduction of BN tends to energy efficiency as compared to COBOM. This technique minimizes the communication cost and provides the boundary accuracy but in sparse network reducing the sensor node cause problem while detecting the object and sensing holes [31].

Chengyue et al. introduces a novel architecture based on both static and mobile sinks. Mobility of mobile SNs based on the instructions of geographic information system. A centroid algorithm presents to optimally calculate the location of the mobile node through static node and both sinks collaborate with each other to locate boundary nodes and collection of information. Moreover, these algorithms accurately detect the location of the object with reduced energy consumption and data transmission and also extends the life time of the network [32][33].

Cluster based continuous monitoring mechanisms and applications for efficient data aggregation provide dynamic event driven cluster formation. Yuan et al. introduces an energy efficient adaptive overlapping clustering method (EEAOC) for continuous monitoring. Using same overlapping structure of clusters, two adjacent sensor nodes can be merged into the same cluster for data aggregation and transmission operations. To overcome the quality of service requirements in the continuous monitoring

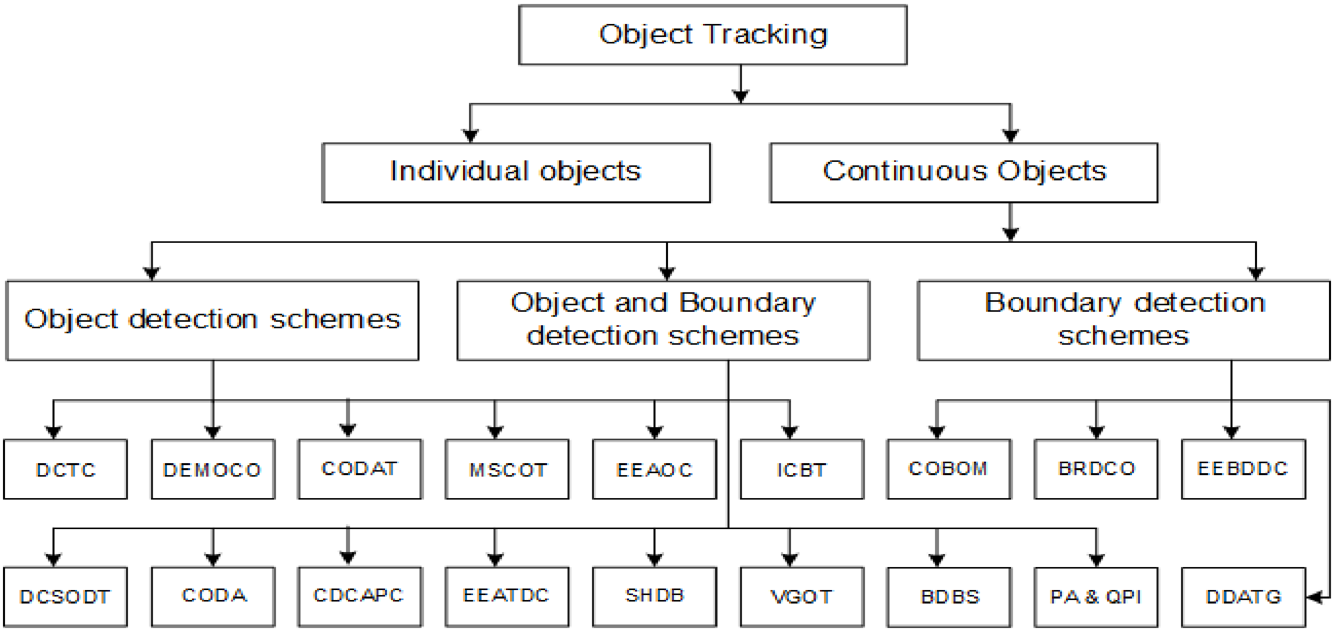

FIGURE 2. **Taxonomy for Object Tracking**

applications also provide hybrid communication procedure by swapping time and event driven mechanisms. The hybrid communication procedure is operated to enhance the accuracy of detection and efficiency of energy [34].

Mahmuda et al. presents energy efficient tracking and localization mechanisms in wireless sensor networks to enhance the network life time. At the boundary areas, an energy efficient cluttering algorithm and Gaussian adaptive resonance theory is presented to aggregate patterns of sensor nodes, clustering patterns on the basis of sensing ranges and efficiently arranging the revived information. To modify instance motion patterns, it allows dynamically creation, learning and updating of the cluster. At the boundary of static clusters incremental clusters are formulate for continuous object tracking within a whole network It also provides accurate localization of dynamic objects using trilateration method [16].

B. CONTINUOUS OBJECT TRACKING AND BOUNDARY DETECTION SCHEMES

In cluster based tracking method network is divided into clusters to support data processing and collaborative communication between sensors nodes and Cluster Head (CH). Different clustering schemes are used such as static cluster, dynamic cluster and hybrid cluster. Xiang Ji et al. proposed a dynamic cluster structure for detecting and tracking (DCSODT) an accurate object boundary. In this approach clustering technique is proposed to minimize the communication overhead. In each cluster, boundary nodes are structured dynamically. The CH gathers information of nearby boundary from other boundary nodes of the cluster and report back to the sink. During boundary change, each CH update its members. This boundary movement speed effects the detection and tracking method. Main drawback of this scheme is energy consumption overhead that is generated when every CH directly/ultimately sends the data to the BS [35].

Chang WR et al. proposed a hybrid cluster with novel Continuous Object Detection and Tracking Algorithm (CODA). CODA uses static/dynamic (hybrid) clustering technique continuous objects detection and tracking, i.e. oil spill, and wild fire. In this mechanism each sensor node monitors and tracks the object boundary that moves within sensing region. Initially, static clusters are configured in the network and sensors nodes are deployed into these clusters. In each cluster, boundary nodes that detected the target they send their sensory data to its own CH through one hop selection method. When the target boundary is detected within each static cluster then each CH organized the BNs with its own cluster and forms a dynamic cluster. Each CH computes boundary values and sends aggregation data to sink. After that, SN computes the boundary for whole object in the region. In this method, cluster construction and maintenance overhead consumes energy [36]. It does not support in emergency situation by the congested data at SN. One hop selection method for reporting the boundary information to the CH also causes energy overhead. It is not suitable for concave polygon shape [37].

Taj Rehman, et al. presented a scheme CDCAPC consistent data collection and assortment in the progression of continuous objects in IoT. In this scheme, congestion diminish, minimizing the data injecting rate and maximum throughput problem is tackled by taking the different link capacity, congested BN selection and residual power of

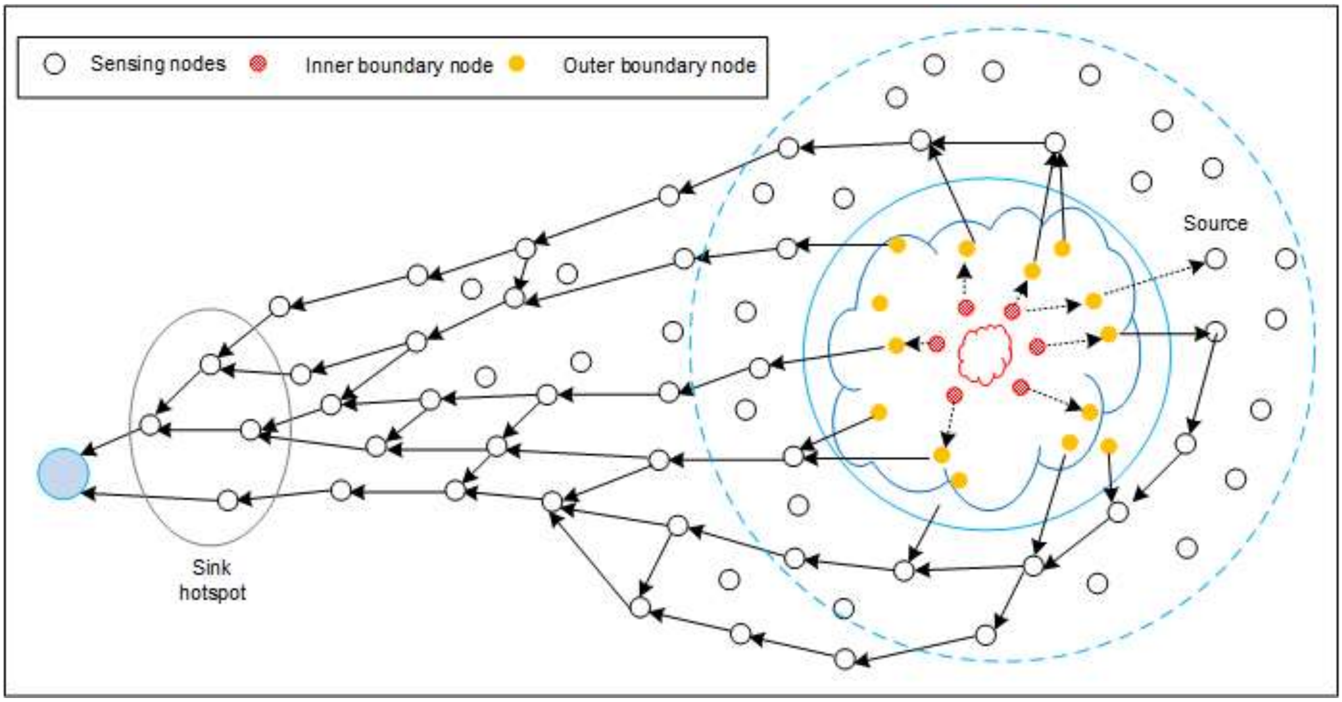

FIGURE 3. Network Connectivity after control algorithm is applied

nodes. Congestion occurs when sensor nodes transmit the data packets to the same target node and their speed of data injecting is greater than the outgoing capacity of the link and processing of the target node. It causes severe damage in critical situation. To tackle this situation a hotspot is formed for consistent data gathering and transmission. For minimization of buffered based packet drop ratio and congestion PCCS preliminary congestion control stage algorithm is used that select the parent node and serve the one data flow among multiple data flows. Parent node selects the child node which has lower data transfer rate and high priority. If the buffer overflowing is still on hand, RBNIC representative boundary nodes identification and congestion control algorithm executes for selecting the uncongested parent node for congestion mitigation. For transferring the data to the parent node few RNs are used. It is obvious that there is no need of congested nodes to neighboring with regular nodes and transmit data to its parent node. After that, hotspot is eliminated and every node checked the next hop by its flag value and calculates the link capacity to transmit the data. This scheme does not provide selection mechanism for boundary nodes only assumptions are created for BNs. Heavy data load may cause energy consumption [38].

In Energy efficient and accurate tracking and detection of continuous objects in WSNs (EEATDC), T. Rehman et al. proposed a two-level boundary localization and detection technique for duty-cycled wireless sensor networks to achieve boundary accuracy through reduction in energy consumption. In duty cycle deployment, a few nodes are active and remaining nodes are in sleeping state which cause energy consumption and reduction in data traffic overhead. When an event occurs, planarized graphs are used to detect the object's coarse boundary and refine the boundary face construction. The sensors around boundary face nodes use four spatial interpolation methods (SIMs) to refine the boundary without awaking the sleeping sensors. Therefore, the candidate inner and outer boundary nodes are selected based on their estimated data to awake and report their data to the SN. The boundary area can be refined considerably by iteration of this refinement procedure. Planarization granularity becomes a problem in boundary nodes [39] when the short sensing range is used in fast object and high dense deployment. There are more chances of sensor nodes to get close to the real detected boundary to send more accurate information to the BS and less energy consumption. However, in some cases long sensing range is used when tracking a slow object and sparse deployment for accurate boundary line but it will cost more energy. Therefore, the short sensing range is better. In case of a static CH, dynamic clustering formation minimizes redundant data transmission [37]. The dynamic cluster formation reduces the number of messages forward to the sink. Therefore, the overall communication cost in terms of energy consumption is reduced [40].

In WSN, continuous nature objects have irregular attributes of expansion and contraction and these attributes cause detection and tracking more challenging. Sensor nodes provide the location of the continuous object and SN estimate the boundary of object using the received information and accuracy of the information based on the boundary node and failure of boundary node affects the boundary detection procedure. Therefore, Sajida et al. presents an efficient failure-prone object detection scheme that uses spatial and temporal attributes of the sensor nodes to detects and recover the failure occur at the boundary nodes without compromising the accuracy of boundary detection procedure. It detects the change and assigns weight to the boundary nodes and restricts the boundary node selection procedure on one and two hop neighbors to achieve optimality. For leader node selection back-off-timer is set at each boundary node as shown in equation (1). BN_{1d} denotes normal boundary nodes,w_1 and w_2 denotes weak and normal boundary nodes, residual energy represents by E_{rd} and stronger bins with BBN_d to select leader node on the basis of maximum energy and a strong node.

$$backoff\_timer = \frac{w_1 BN_{1d}}{w_2 BBN_d E_{rd}} \qquad (1)$$

For efficiency, leader node is selected on the basis of higher number of neighboring boundary nodes and residual energy to aggregate data from the other boundary nodes and transmits towards the sink [41]. Hyun et al. presents a subset selection based algorithm to identify the mobile object. A data aggregation based algorithm introduces for reducing the amount of report messages and sending information to representative nodes. Quadratic polynomial interpolation algorithm for detecting boundary nodes and restore the shape of the boundary [42]. A mechanism utilize hybrid network introduces by Jianming et al. to fill up sensing holes and selecting locations for the mobile sensing nodes. Before Network initialization, voronoi diagram utilize for hole detection[43][44]. Static sensor nodes detect the value toxic air and variation detected by the presented mechanism and estimating the area where variation values are high. Optimum location selection mechanism detecting the variation points for boundary detection and sensor holes also fill up by the mobile sensors. Sensing holes selected on the basis of spatial and variation factors and maintain target list for mobile nodes [45].

For removal of redundancy in space and time domain, a time domain based adaptive sampling was presented. To overcome the designing issue of adaptive sampling in continuous object tracking a new method is presented to visualize the whole sensing field into number of small cells like pixels on visual screens by adopting sensor grid in static clustering based wireless sensor network architecture. To reduce redundancy information of boundary like boundary node, control message and report packets, a picture based image of diffusing objects consider for selecting boundary in the space domain [46].

C. CONTINUOUS OBJECT BOUNDARY DETECTION SCHEMES

The energy efficient continuous boundary monitoring (COBOM) approach was presented for energy-efficient boundary detection. The sensor node broadcast its ID to its one-hop neighbor and matched its current reading. If the current reading is not matched to previous reading, then it saves the information in node's BN-array and then that node becomes a BN. A small number of RNs are chosen for energy efficiency. It is challenging to determine the location for RN's neighbors as BN-Array contains the detection data instead of IDs. The other issue with COBOM is that the BNs and RNs are formed on both sides of the Boundary. It results in yielding more number of BNs and RNs; thus, increasing the communication cost [47].

Y. Zhang et al. offered a scheme (BRDCO) for detecting the boundary region of continuous objects using fog computing by deploying some mobile sensors in the sparse network. By the help of planar algorithms network is initially divided into sub regions and builds a routing map for data transmission. Static nodes are deployed by applying fixed sensing range in sparse network which results in sensing holes' existence. These nodes will transmit their positioning and sensing data to BS by multi hop communication within the region. After analyzing the data, spatial interpolation algorithm (IDW) is applied to calculate the sensory data and predicate the object boundary line. For removing sensing holes, mobile nodes are applied in order to pass through these boundary locations and collect the data for predicting more accurate boundary. Mobility of nodes reduce energy consumption by applying ACO an ant colony optimization algorithm for path optimization of mobile sensors nodes. Transmission overhead occurs by reporting to the sink. Wide adoption of mobile sensors is costly and these are not well suited option for gathering data in special environments, i.e. mountains and uneven harsh places [48].

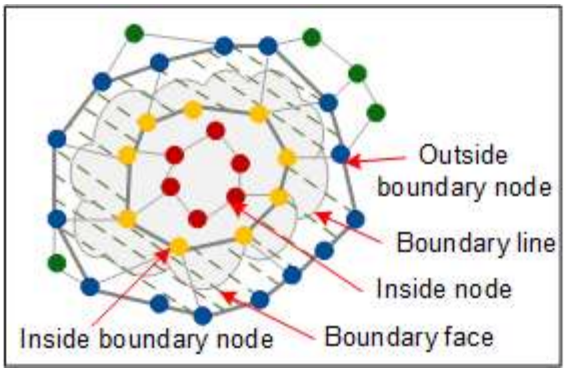

FIGURE 4. Boundary detection object model

A technique was presented for accurate and energy-efficient boundary detection of continuous objects in duty-cycled WSN (EEBDDC). Based on densely deployed activated sensors nodes, a two-level boundary face detection method is proposed. Initially set the certain nodes in duty cycle(active) conditions to monitor the situation. These active sensors recognized the potential events when occurs and also detected the boundary faces of continuous objects by adopting four types of planarization algorithms Gabriel graph (GG), (RNG) relative neighborhood graph, Yao graph (YG) and (LDel*k*) k-localized Delaunay graph. Most of the sensors nodes are in sleep state that because coarse boundary faces somehow. To remove this coarse boundary face, four spatial interpolation methods (SIMs) are adopted for estimating the data of boundary nodes. Based on the sensory data of some nodes, more appropriate boundary face nodes are selected as candidate BNs. These nodes are awakened and route the data to the sink. As a result, sizes of boundary faces are minimized. Thereafter, boundary area will be refined considerably by iteration of this refinement procedure. Assumptions of the Planarization algorithms are not relevant to all cases. Planarization granularity becomes a problem in boundary nodes [49].

Lei et al. presented a scheme for detection and visualization of the dangerous zone in wireless sensor networks. It uses five different types of planarization algorithms to plenarize a WSN and detect the dangerous area of the by partition into inner and outer boundary area for the leakage of gases. Adopt planarization to obtain different topologies and also analyze the impact of these planarization algorithms on the detection of dangerous zone of the gas while considering the node failure scenario. Although presented scheme discussed briefly and analyzed for different case. However, no proper contribution from presenting scheme for highlighted cases on which different existing schemes are analyzed [50].

III. ANALYSIS OF SCHEMES

In this section, we conducted a comparative analysis of schemes and adjust different schemes data in tabular form. Analysis conducted according to their main idea, method, limitations and strong points of multiple schemes are given in Table 2. We conducted an analytical review of these schemes as elaborated in tabular form as shown in table II. This table comprises of continuous object tracking and boundary detection schemes. These schemes are divided into three sections according to the taxonomy. The schemes including [28][30][31][32][34] and [16] provide energy efficient mechanisms for continuous object detection. In [30][31][32][34], communication overhead is reduced. In [31], a hybrid algorithm based on COBOM and DEMOCO reduces the cost and enhances the accuracy. The cluster based schemes [34] and [16] involve efficient mechanisms for object tracking. In the similar vein, an efficient mechanism [28] uses tree based approach. In [35][37][39] and [46], communication cost is reduced and life time is enhanced. Moreover, energy consumption was improved in [39]. In [41][42][45] and [46], efficient object and boundary detection mechanisms were presented whereas fault detection and recovery mechanism were explored n [41]. The redundancy removal mechanism was formulate in [46] to reduce the communication cost of the network while selecting the boundary of the object.

To avoid congestion, a mechanism was presented in [38] to reduce congestion for transmission and packet drop ratio. In [47][48], energy efficient and accurate boundary detection mechanisms were presented. In [47], the packet size was also reduced to diminishing the transmission cost. In [49], four planarization algorithms graph are adopted for identifying boundary faces. Moreover, four spatial interpolation methods are used for estimating the sensory data of boundary sensor nodes. In [50], planarization based five algorithms were adopted to detect and visualize the impact of gas in dangerous area boundary with fault tolerate. Analysis explores that energy efficient object tracking and boundary detection demands reduced communication overhead, data redundancy and packet drop ratio. Accuracy is also a significant factor for object and boundary detection in emergency scenarios.

TABLE 2. Analysis of Continuous Object Tracking based Schemes

Scheme	Basic Idea	Mechanism	Advantages	Limitations
Continuous Object Tracking Schemes				
DCTC [28]	A dynamic convoy tree based approach considers to reduce the boundary nodes that report back to the BS. As the target object	An energy efficient object detecting algorithm. It presents the sequential and localized reconfiguration	Small number of nodes used and Save more energy. Highly reporting rate and	Focus on single object tracking like vehicles, animals and humans. It

	moves convoy tree is constructed dynamically for adding and removing nodes in respected region.	schemes for tree reconfiguration and simulation is implemented in NS-2.	less energy consumption can be achieved by prediction-based scheme.	can be implemented for multiple object tracking with little modifications.
DEMOCO [30]	This technique selected a small number of boundary nodes but selected a subset of them for reporting. When BN received a COZ message. It gets shorter back-off time and wake up early.	Proposed an energy-efficient algorithm that is used to detect and track the boundaries of moving objects, monitors their shapes and movement of continuous object.	Fewer number of BN. Few RN selected for reducing the traffic, energy consumption and communication cost.	Not considered sensing range, next boundary prediction and Don't get precise expected boundary shape.
CODAT [31]	The expansion and shrinking situation of continuous object is presented. In expansion only outer region nodes become and in shrinking only inner region nodes become BN. It presents reporting mechanism sensor node counts the number of most received PCMs waiting time from BN and it is selected as the RN that reports the boundary information to the sink.	CODAT algorithm is hybrid of COBOM and DEMOCO. This algorithm is planned for monitoring continuous shrinkage and expansion of an event and also for holes inside the phenomenon. Furthermore, idea of phenomenon tags is introduced. Its simulation is implemented in Java.	Smaller number of BN and RN reducing the overall energy cost and enhances network lifetime. Presented data structure decreases the overall algorithms communication cost and also enhances the boundary accuracy.	In sparse network with less number of sensor node effects the reliability of object detection procedure and also less efficient in sensing hole detection procedure.
MSCOT [32]	A multi sink based model is presented to enhance the performance of continuous object tracking procedure. A collaborative model to accurately locate and aggregate information from the boundary nodes.	A centroid algorithm divides the boundary nodes to accurately detect continuous objects and boundary nodes to reduce messages overhead.	Reduce energy consumption and transmission overhead and accurate collection of information and tracking of continuous objects	In large networks, less accuracy of boundary detection. Maintenance overhead is high.
EEAOC [34]	A dynamic event driven approach for cluster formation is presented to achieve efficient data aggregation and data transmission. Hybrid communication based approach enhances the accuracy of object detection procedure.	EEAOC algorithm for cluster formation for data fusion and migration. A hybrid communication approach utilizes to fulfil the requirements of the quality of services.	Efficient consumption of energy while gathering and sending data and also reduce the communication overhead and also provide precise detection.	Enhances cluster formation and maintenance overhead and also no boundary detection procedure is considered.
ICBT [16]	A cluster based energy efficient tracking and localization based mechanism to enhance the life time of whole network by reducing energy consumption at multiple points and dynamically incremental clusters are formulating for tracking.	A clustering algorithm and Gaussian adaptive resonance theory is presented at the boundary areas and incremental clusters for tracking. Trilateration method is provide for precise object location.	It provides energy efficient mechanism for tracking of continuous object with in a network and also maintains the stability of the whole network.	It efficiently work in case of small networks and in case of large networks accuracy and stability of the network are reduced.
Continuous Object Tracking and Boundary Detection Schemes				
DCSODT [35]	In this scheme dynamic cluster-based structure is proposed for tracking the movement of boundaries and also make possible the combination and distribution of boundary information. For communication nodes are group into clusters.	Dynamic cluster Algorithm and location-based clustering techniques are proposed to efficiently organize the distribution information at boundary and reduce communication cost.	Effective sensor organization at the boundary and also efficiently propagate the boundary information. To reducing the communication cost.	Energy and traffic overhead will generated when every BN as well as every CH directly send the data to the BS.
CODA [37]	In hybrid clustering method, each sensor node monitors and tracks the object boundary. Static clusters are configured where each node sends data to its own CH. In case of object detection, a dynamic cluster sends data towards the sink after compressing and fusing all the boundary data at CH.	Static / dynamic (hybrid) clustering mechanism to reduce the number of message exchange between the sink and sensor nodes. Performance of clustering mechanism is evaluated by a series of simulations using the Qualnet simulator.	Increased network lifetime by reducing the message exchange rate. At the static CH level dynamic clustering formation also reduces the redundant communication overhead costs.	Cluster formation consumes more energy. Inaccurate boundary for concave polygon shape object. It does not support congestion and missing task recovery.
CDCAPC [38]	The nodes inject enormous data and consume much energy. A hotspot is formed and in that hotspot few RN are selected for consistent data gathering and transmission. After that, hotspot is eliminated and every node checks the next hop by its flag value and calculates the link capacity to transmit the data.	CDCAPC algorithm is proposed for consistent data collection, congestion avoidance and transmitting data with different link capacities for reliable network. It executes PCCS and RBNIC algorithms implemented in java.	Reduce congestion through varying link capacity to transmitting the data. Packet drop ratio is controlled and effectively transmit the high priority data packets in critical situation.	It does not provide any selection mechanism for boundary nodes. Heavy data load may enhances the energy consumption and communication cost of the whole network.
EEATDC [39]	A two-level boundary detection and localization to achieve boundary accuracy through reduction in energy consumption. A few active nodes monitor while remaining nodes are in sleeping condition.	BNs selection proximity graphs and spatial interpolation methods are adopted. It also presents a nodes self-scheduling scheme and simulation is implemented in Java.	Reduces energy overhead, data traffic. Self-scheduling scheme enhances the overall network life time.	Planarization algorithms are not relevant to all cases.
BDBS [41]	Provide optimal boundary selection on the basis of the one and two hope neighbors. Leader selection mechanism boundary nodes to efficiently transmits data towards the SN. Detects and recover the failure without effecting the performance of boundary detection procedure.	Boundary node detection and boundary node selection algorithm utilizes for accuracy in detection or selection of boundary. If a very small change in a phenomenon shape the whole report discarded and not transmits towards the sink.	Efficiently detect and recover the failure occur at the boundary node without effecting the accuracy of the continuous object boundary detection and selection mechanism.	No reliable aggregation mechanism for leader boundary nodes. Load of large amount of data may cause energy consumption at leader node.

PA & QPI [42]	For reducing the amount of report message at boundary nodes and also detects the boundary of mobile object by restoring the shape of boundary.	Data aggregation algorithm for data exchange at RN. Quadratic polynomial interpolation algorithm for accurately boundary detection.	Reducing message overhead and enhancing accuracy while tracking and detecting object boundary.	Selection criteria for representative node not clearly highlighted.
SHDB [45]	A hybrid network based approach presented to filling up the sensing holes while detecting the high variation areas and also formulate a list for mobile sensing devices to detect the optimal location and accurate boundary detection.	Three algorithms are presented by this scheme. First for initial candidate selection for fill up holes. Second for target selection and last for the optimal path selection from mobile node to target location.	Initial hole detection before the start of network. Optimally detecting the path from mobile sensing node to the target location of static nodes	Utilizing large number mobile sensor nodes cause cost overhead.
VGOT [46]	Efficiently tracks the object with virtual grid by utilizing adaptive sampling method to visualize the whole sensing field into number of small cells and also visualizes these cells in time domain to reduce the redundancy.	Boundary node selection algorithm extracts the boundary cells from the sensing field and then acquire the boundary nodes by extracting them from the selected boundary cells.	Reduces redundant data by reducing the control messages while selecting boundary nodes and report packets to BS.	Less accurately acquire the expected boundary. Less clearly highlight the sensing range.
Continuous Object Boundary Detection Schemes				
COBOM [47]	In this technique the sensor node broadcast its ID to its one-hop neighbor and matched its current reading, it saves the information in an array and then that node becomes a BN. A small amount of RNs will be elected among these BNs to report back to the sink.	It presented an algorithm for continuous object monitoring and a clear-cut boundary detection approach. Also defined an Isoline Array to support continuous isoline mapping.	Introduce a data structure to reduces message size to achieve energy efficiency. Boundary is easily reconstructed at the sink and Less packet loss rate.	Report message size is large and consumed more energy. Traffic overhead occurs when BN directly route the data to the sink.
BRDCO [48]	This technique network is divided into regions and builds a routing map by planar algorithm. Static nodes are deployed by applying fixed sensing range in sparse network. For estimating precise object boundary spatial interpolation algorithm is derived. Mobile sensors nodes are applied for more accurate boundary line.	Spatial Interpolation algorithm is adopted for geographic data. To systematize the network gabriel graph and relative algorithms are applied. An ant colony optimization ACO is applied for path optimization of mobile sensors nodes. It is implemented in java.	Mobile sensors provide tenacity of perceptual holes and boundary accuracy improvement. Energy consumption is achieved through mobility of sensor nodes.	Widely use of mobile sensor nodes results in cost overhead. Mobile sensors are not appropriate choice in special environments, i.e. mountains and uneven harsh places.
EEBDDC [49]	For improving the boundary accuracy, boundary faces of continuous objects are constructed in duty cycle dense environment. After detection the boundary face nodes their data is estimated through spatial interpolation and based on the estimated data appropriate BNs are selected.	Four planarization algorithms (GG), (RNG), (YG) and (LDel*k*) graphs are adopted for identifying boundary faces, and four spatial interpolation methods (SIMs) are used for estimating the data of BN. Simulation is implemented in Java.	Refinement procedure refine the boundary by reducing half of boundary face area and few sensor nodes for reducing energy consumption when nodes deployed in dense fashion.	Selection of duty cycle nodes enhance energy cost and network planarization efficiency. Granularity of the planarization is always a problem.
DDATG [50]	Provides a mechanism to detect and visualize the dangerous area for leakage of gas and divide the dangerous zone into inner and outer boundary areas to visualize the emission and spreading of dangerous gas and also consider the node failure criteria.	Planarization based algorithms detect and visualize the impact of gas in dangerous area by splitting the whole area into outer and inner boundaries. YG scheme detects smaller size of critical area.	Algorithms are selected for detection of small object. YG scheme detects small object precisely and also considering fault tolerance criteria.	Planarization algorithms are irrelevant. No proper algorithm presented for dangerous gas detection and for fault detection procedure.

IV. OPEN RESEARCH CHELLANGES

The existing literature covers a variety of solutions for continuous object tracking. However, new challenges arise in different application scenarios. We explored a number of open research challenges as follows.

A. SENSING RANGE AND ENERGY CONSUMPTION

Sensing range affects the performance of network and energy efficiency during continuous object tracking. It involves a large amount of communication among various sensor nodes [39][51]. There is a tradeoff between sensing range and energy consumption [61]. Large sensing range can reduce packet drop ratios and reducing communication overhead but it requires more energy for each message transmission. It is quite challenging to manage it efficiently to enhance network lifetime [52][53].

The boundary nodes interact with each other and also report back to the BS for tracking the continuous object by consuming additional energy [54] [59] [60]. Therefore, size of report message is reduced for energy efficiency in [30] and if only those nodes send data to CH which have new boundary information. As a result, it conserves the total energy and prolongs the overall network lifetime [37] [62]. It is quite challenging to choose short range or long sensing range. If there are small numbers of nodes in the sparse network to report back to the BS, then it would require larger transmission ranges to make communication possible [58]. In dense network, for overlapped sensing areas it is important to consider more short sensing range of sensor nodes. The sensor node should adjust its sensing range according to the specific conditions so that it saves energy and monitor the object for longer time [47]. In [55] and [56], sensor nodes were organized in sets for energy constraints because extensive amount of message exchange between nodes consumed more energy and communication overhead occurs. It aimed to cover large set of targets sensor nodes. In [57], the main focus is for known location targets monitoring where less power is consumed by keeping other nodes away from the communication.

B. ACCURACY OF BOUNDARY DETECTION

In continuous object tracking, accurate boundary detection of object is more challenging aspect [63][64] which demands proper nodes deployment [65]. Continuous objects have a tendency to change shapes as well as to blowout under the wind pressure, therefore, accurate and timely tracking of boundary movement of such objects is a challenging issue [37]. Toxic gas leakage and diffusion are difficult processes that cause severe damages and air pollution. It is quite critical to timely and accurately identify the source and spreading direction [47][30]. Although, the schemes [41][49][39] achieve accurate boundary detection through duty cycle sensor node in dense network. However, accuracy can be further improved [66]. The IoT enabled applications track the toxic gas leakage in industrial area [67][68], oil spills and fire detection. It demands the accurate boundary detection for dependable solutions [48]. It opens a new set of challenges that must be resolved by the researchers through innovative solutions.

C. BOUNDARY FACE AREA LOCALIZATION

The boundary face area detection is quite challenging while achieving accuracy and reducing the energy consumption [49][73]. In [39], the energy consumption is reduced by sharing the messages to the nodes that are located on critical positions near boundary face. It is also quite challenging to discover more number of active nodes that can play as backup role for the critical nodes in boundary face area. It is quite challenging task to accurately predict the continuous object while it is spreading in multiple directions with different speeds. Thus issue is solved through localization of boundary face area. The researchers should also present the schemes that predict the chances of spread towards nearby critical locations where precious and valuable records or items are placed. In case of fire, there may be the nearby petroleum reservoirs or ammunition stores that must be protected by identifying the boundary face and its spread with a certain speed.

D. TRANSMISSION OVERHEAD

It is quite challenging to reduce the communication cost while ensuring the accuracy and timeliness for continuous objects tracking and detection which involves large number of sensors [69] [72]. It becomes more challenging when continuous object disperses in an extensive physical area or move with a high speed [71]. Communication overhead is minimized through duty cycle sensor deployment in dense network to improve boundary face area [37][49] [39]. In emergency situation, data transmission is extremely challenging factor to detect the event boundary and effective utilization of network link capacity. It requires massive communication and transmission overhead when all the sensor nodes report the data to the sink. It also causes congestion which results in severe packet loss and collision. To address this challenge, the scheme [38] minimized the communication cost, energy consumption and utilize the maximum throughput. To further improve it, the fog nodes require high computational capacity to process and analyze the data from sensors [70]. It is quite challenging to achieve accurate boundary with minimum transmission overhead in real-time scenarios [48].

E. CONGESTION AND DATA LOSS

It is a challenging issue in dense deployment where congestion occurs due to excessive communication in a specific time bracket [74]. It results in data loss even in emergency scenarios [49]. To address this challenge, few active nodes are used to monitor the continuous object and minimize the congestion and data traffic, rest of the nodes are in sleeping state [39][49]. It reduces the size of boundary faces and the data traffic is also minimized. To reduce congestion, the researchers should focus on improving the data packet loss, end-to-end and hop-by-hop delay, high precedence data delivery as in [38][72].

F. REDUCTION OF ACTIVE NODES

A continuous object usually spread in large areas which involve a large number of active sensor nodes to detect and track it. Massive communication is involved when all the incident nodes transmit their sensory data and position information to BS. Generally, energy consumption is reduced by decreasing the number of boundary nodes and reducing the reporting information size [41]. To address this challenge, the continuous objects should be monitored by minimizing the communication overhead with fewer number of active nodes selection [49][39]. It is also challenging to identify the trajectory of move for continuous object which involves taking data from a large number of active senor node. It opens a new horizon for the researchers to present dependable solutions that involve less number of active nodes and ensure the reliable communication without missing any relevant data from critical region.

V. CONCLUSION

IoT empowered applications are quite beneficial for the tracking and monitoring of continuous objects including toxic gas, oil spills and fire. In this paper, we have investigated the existing and state of the art work on continuous object tracking and boundary detection. We presented a taxonomy to arrange the literature for both object and boundary detection mechanism. Moreover, FoG assisted structural design are also explored for boundary detection. We performed the analysis for the schemes in literature. It has been identified that mostly object tracking and boundary detection techniques aim to diminish energy consumption, congestion and transmission overhead. Moreover, duty cycle mechanism of sensors is used for minimizing the energy consumption to prolong the network lifetime. Finally, we identified the open research challenges that must be solved to provide the dependable solutions. In future, we shall analyze the deployments where drones can extract the data from sensor nodes and CH as well during continuous object tracking.

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