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Mitigating Workload Imbalance in Hazardous Situations through Mobile Sink Coordination

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Abstract: This paper addresses the critical issue of workload imbalance in hazardous situations, where uneven distribution of tasks can impede effective response efforts. The proposed solution revolves around the innovative concept of mobile sink coordination, leveraging adaptable and agile data collection points. The study emphasizes the importance of real-time decision-making, resource optimization, and collaborative efforts to ensure a well-coordinated response. The overview establishes the significance of workload balance in hazardous events, introducing mobile sink coordination as a promising solution. Mobile sinks, strategically deployed, dynamically distribute tasks based on evolving demands, thereby enhancing response efficiency. The study unfolds by exploring the technical aspects of implementing mobile sink coordination, including communication protocols, route planning, and resource allocation algorithms. By integrating mobile sink coordination into hazard response strategies, the study envisions a future where data-driven decisions are bolstered by dynamic task distribution. Through empirical analysis and simulations, the paper aims to demonstrate the tangible benefits of this approach in mitigating workload imbalances, enhancing the resilience of response teams, and contributing to safer and more efficient outcomes in hazardous situations. Ultimately, the study aspires to transform the way tasks are allocated and executed, advancing hazard mitigation and response strategies for a safer and more effective future.

Keywords: *Opportunistic communications, Energy Efficient, Disaster Area Network.*

1. Introduction

Network of wireless sensors or WSN obtained significant attention due to its ability to transfer, gather and segregate information in harsh environments where battery replacement is not feasible. Hence for application of Wireless Sensors Networks the transferring of information packets in a manner that uses lesser energy is extremely important. This paper proposes an scheme of routing that is efficient from an energy perspective which puts into technologies of mobility of sink and clustering. The proposed scheme separates the field of sensors in parts. In every sectors a selection of Head of Cluster or CH is to be made on the basis of the importance of the constituents. The nides that are members ascertain that power usage of multiple roads of routing and makes the choice of scenarios that are the most optimized. For the reason of communications from one cluster to another cluster that use of the algorithm of Greedy the connection in chain are done for CH. The outputs of simulations demonstrate that the schemes that have been under proposition may outmatch same type of research works like ECDRA or CCMAR. The paper also explores the impact of multiple network variables on the network's working and proposes methods to enhance its performance. Mitigating Workload Imbalance in Hazardous Situations through Mobile Sink Coordination" presents a proactive approach to addressing workload imbalances in high-risk scenarios by employing mobile sink coordination. This study focuses on situations where uneven distribution of tasks or responsibilities can hinder effective response and recovery efforts. By strategically coordinating mobile sinks, which act as dynamic data collection points, the research aims to optimize resource allocation and ensure a balanced workload distribution. The study's overview sets the stage for an exploration of how mobile sink coordination can enhance decision-making, resource utilization, and overall effectiveness in hazardous situations. In hazardous situations, where the stakes are high and rapid response is critical, the imbalance in workload allocation among various tasks can lead to inefficiencies, delays, and even compromised outcomes.

The study recognizes the significance of addressing this challenge and proposes a solution that leverages the concept of mobile sink coordination. Mobile sinks, in this context, serve as dynamic entities that can move strategically within the hazardous environment to collect and process data. By coordinating the movement of these mobile sinks, the study aims to distribute workload more evenly, ensuring that critical tasks receive timely attention and resources are optimally utilized. The overview of this study introduces the concept of workload imbalance mitigation through mobile sink coordination. It highlights the significance of this approach in scenarios where hazardous situations demand swift and efficient actions.

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The overview lays the foundation for exploring the intricacies of mobile sink coordination, its impact on decision-making processes, and its potential to enhance the overall effectiveness of response efforts in hazardous situations. The study's objective is to contribute to the development of strategies that alleviate the challenges posed by workload imbalances in critical situations. By harnessing the power of mobile sink coordination, the research seeks to enhance the coordination of resources, improve the allocation of tasks, and ultimately ensure a more synchronized and effective response to hazardous events. As the study unfolds, it will delve into the methodology, empirical findings, and potential applications of this innovative approach, shedding light on its practical implications and the value it brings to the realm of hazard response and mitigation. The study "Mitigating Workload Imbalance in Hazardous Situations through Mobile Sink Coordination" is rooted in the recognition that hazardous situations demand a well-coordinated and balanced response to ensure effective outcomes. In scenarios where tasks and responsibilities are not evenly distributed, there is a risk of overburdening certain resources or neglecting critical areas. This can hinder decision-making, delay response efforts, and even compromise the overall success of the response and recovery process. The innovative solution proposed in this study centres around the concept of mobile sink coordination. Mobile sinks, which are adaptable and agile data collection points, hold the potential to dynamically distribute the workload across different areas of focus within the hazardous environment. By strategically coordinating the movement and deployment of these mobile sinks, the study seeks to ensure that resources are allocated based on the urgency and criticality of tasks, leading to a more balanced and efficient response.

The study's overview sets the stage for a deeper exploration of how mobile sink coordination can mitigate workload imbalances in hazardous situations. It emphasizes the importance of real-time decision-making, resource optimization, and collaborative efforts in ensuring an effective response. By integrating mobile sink coordination into hazard response strategies, the study envisions a future where data-driven decisions are bolstered by a dynamic distribution of tasks, resulting in more streamlined operations and improved outcomes. As the study unfolds, it will delve into the intricacies of implementing mobile sink coordination, examining factors such as communication protocols, route planning, and resource allocation algorithms. Through empirical analysis and simulations, the study aims to demonstrate the tangible benefits of this approach in mitigating workload imbalances, enhancing the resilience of hazard response teams, and contributing to safer and more efficient outcomes in hazardous situations. In hazardous situations, the efficient allocation of resources and tasks is of paramount importance to ensure a swift and effective response. The study "Mitigating Workload Imbalance in Hazardous Situations through Mobile Sink Coordination" delves into the pressing issue of workload imbalance that can hinder response efforts. This imbalance often arises due to variations in task complexity, location, and urgency, leading to suboptimal resource utilization and potential bottlenecks. The concept of mobile sink coordination offers a promising avenue to tackle this challenge. Mobile sinks, which can be equipped with data collection capabilities, provide a dynamic means to distribute tasks and responsibilities in real-time. By strategically coordinating the movement of these sinks based on the evolving demands of the situation, the study aims to alleviate workload imbalances and enhance the overall efficiency of response operations. The overview of the study sets the context for understanding the significance of workload balance in hazardous situations and introduces mobile sink coordination as a potential solution. It highlights the multifaceted nature of hazardous events, where seamless coordination, informed decision-making, and resource optimization are crucial components for success.

The study's ultimate goal is to contribute to the development of strategies that empower response teams to effectively manage workload imbalances. By harnessing the capabilities of mobile sink coordination, the research seeks to create a responsive framework that adapts to the dynamic demands of hazardous situations. As the study progresses, it will delve into the technical aspects of implementing mobile sink coordination, the methodologies for optimizing sink movement, and the empirical validation of its effectiveness through simulations and real-world scenarios. In essence, the study "Mitigating Workload Imbalance in Hazardous Situations through Mobile Sink Coordination" aspires to enhance the resilience and efficiency of response efforts in the face of hazardous events. By embracing innovative approaches like mobile sink coordination, it aims to transform the way tasks are allocated and executed, ultimately contributing to safer and more effective hazard mitigation and response strategies.

2. Related Works

In [1] a novel scheme was introduced for classifying existing resource-aware **forwarding mechanisms** designed for **intermittent connectivity environments**. This scheme categorizes **algorithms** based on their primary resource consideration: energy, buffer space, bandwidth, or a combination of all three (hybrid). Subsequently, an analysis of various established **algorithms** is presented, highlighting their advantages and shortcomings. This analysis aims to equip future researchers with valuable insights for developing novel **forwarding strategies** in the domain of **dynamically**

connected systems. The article in [2] explores the application of reinforcement learning, specifically leveraging the Deep Q-learning technique, to enhance packet forwarding in opportunistic networks (Oppnets). The approach utilizes Q-values to identify the most suitable intermediary **connecting point** for transmitting a packet from a source **connecting point** within the Oppnet to its desired **ending point**. Simulations conducted using the ONE tool demonstrated that this "Q-Routing" method exhibits superior efficiency compared to established protocols such as Epidemic, Maximum Probability (Max-Prob), and Probability Routing Protocol using History of Encounters and Transitivity (PRoPHET). A novel routing protocol for Wireless Sensor Networks (WSNs), termed MOORP, is presented in the paper [3]. MOORP leverages both optimal forwarder selection and the Dragonfly algorithm for route optimization. It employs a two-fold approach:(a)Forwarder Selection: Residual energy and Euclidean distance metrics are utilized to meticulously select the most suitable intermediary connecting point for forwarding data packets. This ensures both energy efficiency and directness in routing choices.(b)Route Optimization: The Dragonfly algorithm, inspired by the collective hunting behavior of these insects, is then employed to identify the optimal path between the chosen forwarder and the designated ending point. This algorithm effectively navigates the network's dynamic topology, seeking the most efficient route for packet delivery. By combining these distinct strategies, MOORP strives to achieve efficient and reliable data transmission within WSNs. In the journals cited in [4-11] more protocols have been proposed that use opportunistic routing in disaster areas.

3. Problem Identified

The advancement of technologies of computers and communications over wireless channels, along with nano-electronics technical advancements, has led to the creations of small and cheap and multi-usable sensor-arrays. These sensors are typically deployed in target areas in a random manner to monitor physical features such as temperature, humidity, and pressure. The collected data is transmitted to a data collector (sink) through cooperative methods, usually multi- hop, which then relays it to a remote server for further analysis. These sensors can also self-organize and form wireless sensor networks (WSNs) based on local collaboration. WSNs possess favourable characteristics such as high fault tolerance, real-time data transport, rapid deployment, and self-organization, which make them ideal for deployment in unfriendly or harsh environments, particularly in military or disaster surveillance scenarios. Furthermore, WSNs are widely used in applications such as industrial product line monitoring, agricultural and wildlife observation, healthcare, and smart homes. Sensors in WSNs are typically powered by batteries with limited energy, making it impractical to replace them due to the large number of sensors and high cost involved. One possible solution is to equip sensors with higher-capacity batteries, but this is difficult to achieve as the performance of batteries has already reached its limit and cannot be improved easily. Therefore, energy efficient routing protocols or algorithms are essential to address the energy shortage issue in WSNs. In addition, unbalanced energy distribution among sensors is also a challenge in WSNs. When a sensor fails, the network's performance deteriorates due to the formation of "fade zones" around the dead node. This phenomenon, similar to energy holes, is caused by the "hot spots" problem, which arises in WSNs with a static sink and fixed network topology. Nodes located near the sink experience heavier traffic as they are responsible for forwarding data packets to the sink, leading to faster energy depletion. As the sink is stationary and the network topology remains unchanged, the energy distribution becomes more uneven over time. Network lifetime, which is commonly defined as the time when the first node fails, is a crucial measure of the network's performance. Considerable research efforts have been devoted to addressing the issues of energy efficiency and energy balance in wireless sensor networks (WSNs), and significant progress has been made in this area.

Clustering is a popular approach to reducing the energy consumption of WSNs by dividing sensors into clusters based on specific rules. Cluster heads (CHs) are elected to act as relay nodes for their members, and data fusion techniques can be employed in CHs to reduce redundant data and alleviate the burden on them. The low-energy adaptive clustering algorithm (LEACH) is a classic routing protocol that utilizes clustering, but CH selection using this protocol is considered to be flawed and is being further investigated. To address the problem of unbalanced energy in WSNs, sink mobility technology has been proposed as an effective method. In mobile sink-supported WSNs, the sink is typically mounted on intelligent vehicles or robots, allowing it to move freely around the sensing field. Sink mobility technology offers several advantages. First, it can alleviate the "hot spots" problem by redistributing energy consumption more evenly. Second, it can significantly reduce the total energy consumption by shortening the transmission distance between communication pairs, provided that the sink mobility pattern is well designed. Third, it can reduce latency and increase network throughput. Finally, it can ensure network connectivity even in sparse or disconnected sensor networks. Despite these benefits, sink mobility also presents challenges. The location of the mobile sink should be frequently broadcast or predicted by sensors, which may increase network burden. Additionally, the sink's movement pattern must be well designed to facilitate data transmission and cooperation with local nodes.

4. Proposed Solutions

This research paper considers a circular sensing field with N sensors, each having a unique ID. The sensors are assumed to be randomly deployed by vehicles and stationary after deployment. They can exchange information about their locations with each other. All sensors start with the same amount of initial energy, which cannot be replenished. Once a sensor's energy is depleted, it becomes useless. The transmission power of sensors can be adjusted based on the communication distance. A mobile sink is deployed in the sensor field and is free to move around. Its moving trajectory is well-scheduled and it has unlimited energy and communication range. The sensor field is divided into several sectors based on the geographical position of the sensors. These assumptions form the basis of the network model.

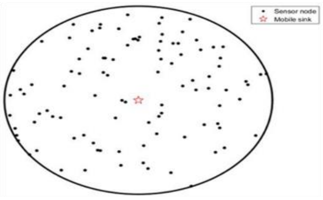

Fig 1 Distribution of Sensor Nodes with respect to the Mobile Sink in a Theme Park

In this study, we utilize an energy model that has been used in previous research [10]. As depicted energy consumption can be divided into two categories: transmission consumption and reception consumption. The transmission component involves signal generation and amplification. The amplifier uses two different power levels to boost the signal depending on the transmission distance. As a result, the energy model for transmission is divided into a free space model for short-range communication and a multi-path fading model for long-range communication.

5. Intra-cluster Communication

To ensure a longer network lifetime, it is important to minimize long-distance communication during intracluster communication. In our proposed scheme, member nodes can evaluate the energy consumption of different routing paths to select the most efficient relay node or to transmit data directly. As pointed out by Lambrou et al. [9], transmission consumes around 1000 times more energy than computation. Therefore, it is beneficial for nodes to choose a routing path that minimizes transmission energy consumption by performing calculations. The energy consumption of a routing path that uses direct communication can be calculated as follows. In our proposed scheme, intra-cluster communication can consume a significant amount of energy and decrease the network lifetime. To address this issue, member nodes can evaluate the energy cost of different routing paths and choose an optimal relay node or direct communication to transmit data. As discussed in Lambrou et al. [11], transmission consumes about 1000 times more energy than computation, making it preferable for nodes to select a better routing path through computation. The energy consumption for the direct communication route can be calculated as follows, where d(Si, CHSi) is the distance between node i and its corresponding CH, and E1(Si, CHSi) or E1(Si, Sj) represents the energy cost of direct communication between source and target nodes. If the source node is distant from its CH, a relay node j will be chosen to forward the data package. The total energy consumption for the entire routing can be computed using:

$$E_i(S_iCH_{si}) = \left\{ \begin{array}{l} l.E_{elec} + l.\varepsilon_{fs}.d(S_i,CH_{si})^2 if d(S_i,CH_{si}) < d_0 \\ l.E_{elec} + l.\varepsilon_{mp}.d(S_i,CH_{si})^4 if d(S_i,CH_{si}) \geq d_0 \end{array} \right\} \quad (1)$$

The evaluation done by us on workings of the scheme under proposition against two other algorithms, ECDRA and CCMAR, using similar network model. The network lifetime is characterized by the times elapsed until node that is the first dies, and was used as the performance metric. Like it has been illustrated in Figure 7.2, our schema outperformed ECDRA and CCMAR in case of the metric of lifetimes of the network. CCMAR's structure of chains because of intra-cluster communication resulted in heavy forwarding burden and straight-away networking from the sinks of mobile information to the CHs, causing high usage of power of CHs. ECDRA considered only sink of mobile data that is locomoting towards the external region of the field of sensors leading to boundary sensors dissipating extra power while depleting faster. Furthermore, comparison was made by us on the utilization of power algorithms, as shown in Fig 7.2. Our proposed schema still had the best performance, with CCMAR exhibiting unnecessary energy dissipation due to excessive forwarding, resulting in higher energy consumption than the other two algorithms. ECDRA consumed more energy than our schema due to the longer mean communication distance. In conclusion, our proposed schema's energy-efficient routing path calculation and selection mechanism led to better performance than the other two algorithms.

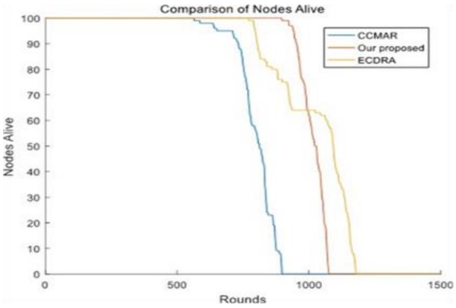

Fig 2 Comparison between network lifetime different algorithm

6. Performance Study in WSN

Inside the current part, we explain the design of our EEOR or Routing in Opportunistic and Energy -Efficient protocol in an environment of modelling of a network of wireless domain on the basis of OS like TinyOS, considering a scenario where multiple source-destination pairs exist in a randomized deployment of Wireless Sensor Networks. The design proposed by us addresses multiple important problems. Firstly, every node in a list of forwarder should have an agreement over the next operation on the basis of importance that come with the packet. This necessitates the conservation of power and raise the throughput. However, the increased communication overhead due to agreement must not outweigh the improvements in the owrkings that have come after the usage of EEOR schemes. Secondly, the scheme of EEOR must handle communications traffics in an efficient way and manage congestion to avoid bottlenecks, reduce loss of packets ratios and use lesser energy. To address the current issues there is a necessity for us to bring into consideration multiple factors, such as ensuring the information traffics that are flowing from beginning nodes never goes above the capacities of the wirelessly connected network. Dynamic adjustments of network flows by all source nodes are essential to maintain stability in the ongoing flows within the wireless network. Consequently, ensuring that the amplified overhead does not surpass the performance gains derived from EEOR becomes a crucial consideration. They can fit-in increased number of flows into networks in case it hasn't met the targeted values or decrease their flow otherwise. Inside the current part discussion have been held by us on design details of our Energy-Efficient Opportunistic Routing (EEOR) protocol, which we simulated in a TinyOS-based WSN environment. Our simulation considers aspects in which many different source/destination pairs of a WSN deployment in a randomized manner. The scheme proposed by us tackles several challenges. Firstly, every node inside the list of forwarder must have an agreement over the next operation on the basis of packet priorities or resuce usage of power and raise throughput. This agreement involves communication, which increases wireless network overhead. Hence, it is imperative to guarantee that the heightened overhead does not overshadow the performance improvements achieved by EEOR. Secondly scheme of EEOR must handle in an efficient manner the traffic of the network by avoiding congestion and decreasing ratio of loss of packets while saving energy costs. This requires dynamic adjustment of network channelings from starting nodes, which must never go above the capacities of the wirelessly connected network. Thirdly singular data-chunks may come to final nodes via different roads, involving increased number of nodes that are wirelessly connected and increasing traffic burden. Therefore, we introduce a penalty scheme to punish selfish nodes that select too many potential forwarders. Fourthly, nodes can use message that have been overheard to bring down the necessity for ACK messages, which is an significant strategies incase of our design. Simulation results show that this strategy improves workings of the framework. The implementation of the scheme proposed by us on TOSSIM and performed test of extensive mature under different network environments. The results were compared with those of ExOR for unicast scenarios, considering energy utilization, packet loss ratio, end-to-end delay, and packet duplication ratio. The experimental findings indicate that the protocol developed in this study surpasses ExOR in performance.

6.1 Description of the IoT network architecture for designing of smart disaster-resilient theme park

The primary aim of implementing IoT technology in smart environments of modern theme parks revolves around the monitoring of physical and chemical changes, with the subsequent transmission of this data towards a central information stack to analyze mode deeply [8]. IoT nodes exhibit varying sensing capabilities, and to conserve energy, they stay away from straight-away networking through each other. Instead, they transmit the data they've collected to designated routing nodes (RNs). These RNs then aggregate and transfer aggregated information to Gateways (GCN), typically communicated to web for remotely collecting information and putting them in processors. These networking patterns persists until Internet-of-Things technologies ceases to function. However, IoT networks face a multitude of challenges, with energy consumption during communication standing out as the most significant hurdle. To enhance the longevity of IoT networks, the adoption of power-thrifty methodologies to route packets becomes crucial. This section introduces the models of systems under assumptions in order to newly proposed CCEA routing protocol.

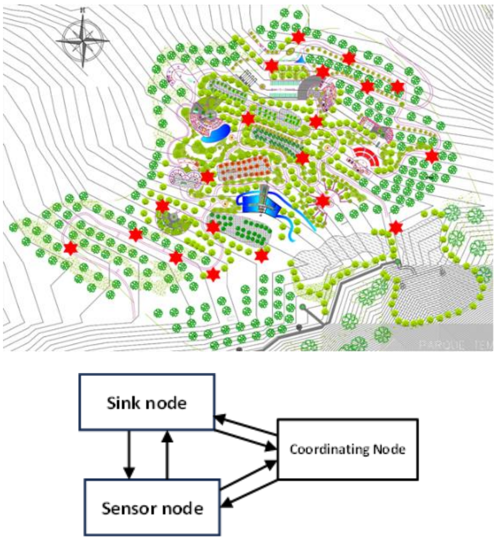

Fig 3 Outline of the Theme Park which is built by the utilization of Autocad 2020. The red stars represent the placement of the sensor clusters in the Theme-park. Block diagram demonstrating interactions of different nodes

Within this segment, we present an innovative strategy for delivering data in an energy- conscious manner within the realm of energy-restricted IoT. Let's consider the scenario where GCN designates a sensor, denoted as n, for data retrieval based on its harvested energy. The quantity of relay nodes, randomly selected inside communicating radius of sensors n, may be described using space-based process that has Poisson characterisitcs denoted as X.

Consider a sensor n positioned at a position $z \in \mathbb{R}^2$. Definition of (z, X) like a minimal space from the location of the sensor z to the closest position in X, where $l(z, X)$ is less than or equal to r. This evaluation only takes into account common control channels. Given that X is a spatial Poisson process, the condition $(z, X) \leq r$ holds true if and only if there exists at least one relay node RN within a disc of radius r centered at the sensor location z, denoted by $d(z, r)$. In conclusion, the likelihood of having a neighboring relay situated within the transmission radius of the sensors n can be expressed as follows.

$$(l(z, X) \leq r) = 1 - e(\beta harvAd\ (d(z, r))) \qquad (5)$$

where Ad represents dic-size $d(z, r)$, and in which $\beta harv$ represents sensor power harvesting rate.

The expression $(\beta harvAd\ (d(z,\ r)))$ refers to the likelihood that there are no relay nodes present within the transmission ranges of sensor n. In other words, it represents the probability that the network lifetime of the sensor n's neighborhood has come to an end. Once the lifespan of the nodes in the surrounding vicinity concludes, it is presumed that the IoT network has ceased to function. Consequently, considering $(nj\ )$ as the transmission cost function GCN to RNj, $g(n)$ representing power levels of adjacent Remote Nodes, $h(n)$ denoting least distances from a neighboring GCN to RNj, and $i(n)$ as the starting power of nearby RN. Methodology employed in this approach hinges on a "cognition process" with three primary factors governing data routing: (a) Evaluation criteria, where $f(nj\ )$ represents prices of sending from neighbors GCN to RN, and $h(nj\ )$ was defined as the minimum of $f(nj\ )$, as ensured by the algorithm outlined in line eleven to eighteen in Scheme 1.a. (b) Selection criteria, determined by the condition $g(h(nj\ )) > i\ (h(nj\ )) * 50\%$, specified in lines 19 to 21.(c) Termination criteria, which is met when either every single-jump Remote Nodes are non-operational, / when $(l(z, X) \leq r)$ equals 0.

6.2 Codes for Disaster Sensor Network Algorithm:

Functions: Process of Cognition in CCEA

Inputs

Get RN

Outputs

Route Node's (RN) index taken by CCEa for sending information packets to GCN.

```
Start_Initializing:
Hops Count =0;
//for RNs at the start of Rounds. Identification of starting RN for this round.
List every neighbouring RNs indices from the starting RN
If starting RNs have single-hop, transmit direct to GCN.
Else If there is one Routing Node attached with this Routing Node
For every starting RN indexed 'j' do
    $(n_j)$= Length (Nearby RN to GCN)
        $(n_j)$= Power (Nearby RN's energy)
    $h(n_j) = min(f(n_j))$
        $i(n_j)$= StartingPower (RN's starting Power)
End
If $(h(n_j)) > i(h(n_j)) * 50\%$ Chosen RN Index = $g(h(n_j))$
End
End
```

The algorithm mentioned above has been followed while building Internet-Of-Things networks built to equip a typical theme park (design demonstrated in Fig. 4 along with placements of sensor nodes of the IoT). The simulation of this IoT architecture of network of sensors was done on the Omnet++ platform. The main idea behind creation of this new algorithm for setting up communication between different IoT node inside theme park is to ensure transfer of data lumps from each point to the next point by the minimum number of hops between routing nodes and also by expending the minimum quantity of electrical energy while the packet transmission is being performed and this we believe will enable the deployed network stay active for a longer duration without recharging of the batteries of each one of these IoT sensor nodes.

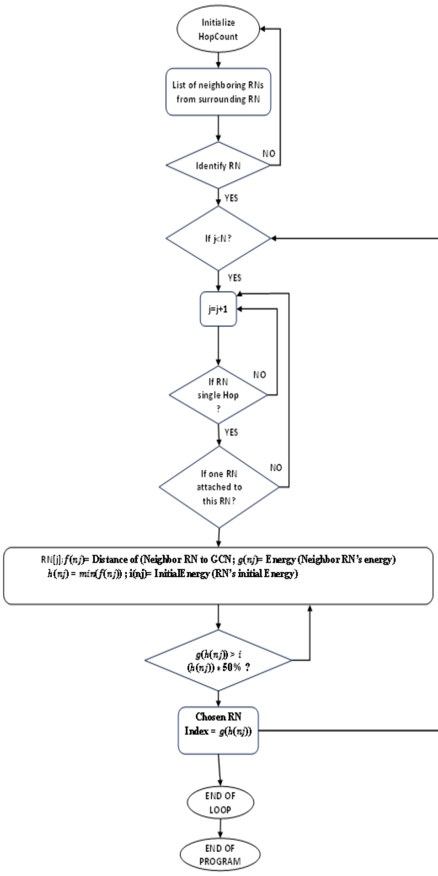

Fig 4 Flowchart for operationalization of CCEA algorithm of integrated Sensor Operation and Monitoring

Given in Fig. 5 is the program which have been followed while developing the CCEA algorithms for the operation and monitoring of the sensor nodes. The y-axis in the graph presented in Fig. 6 represent the consumption of energy in the network when ten in the number of node(s) representing the size of the networks. Numerical value of the node(s) under consideration is raised in multiples of 10 and we have considered networks of sizes ten nodes, twenty nodes, thirty nodes, forty nodes and fifty nodes respectively. Y axis is measured in μJoules (or 10^(-6) Joules). These sensor nodes are necessary in order to inform the uses of the theme park in case of any catastrophe about how to evacuate amusement realms while the scenarios are growing adverse.

7. Results and Discussions Performance Evaluation

We conducted extensive tests for comparison of the working of our EEOR protocol with ExOR on the basis of the net power that have been sued and the rate of losing of packets and delays from one end to the other end and duplicating of packets. To ensure a fair comparison, we used the same maximum magnitude of the lists of the forwarders incase of either schemes and set each batch to have a singular data encapsulation for ExOR. The comparison done by us in case of usage if power for differing node operations, such as sending and receiving, as they dominate the power usage inside the networks. Fig. 2 and Fig. 3 present the times of reception and net times of transferring and reception in case of every node sthat are connected wirelessly in ExOR and EEOR schemes. In the images, we observed that ExOR has larger transmission and receiving times than EEOR. This is because in ExOR, a node will always add more neighbours to its forwarder list for a packet under the penalty constraint, whereas in EEOR, a node considers not only the expected cost of sorted neighbours but also the increment cost by adding a node to the forwarder list. Thus, a node in EEOR will not add a new neighbour to the forwarder list if it increases the expected cost. Additionally, inside ExOR, a node's the price that is under expectation is dependent upon the neighboring nodes with the least value of ETX, while in EEOR, the cost under expectation is under determination through the current list of forwarder that si under selection and link.

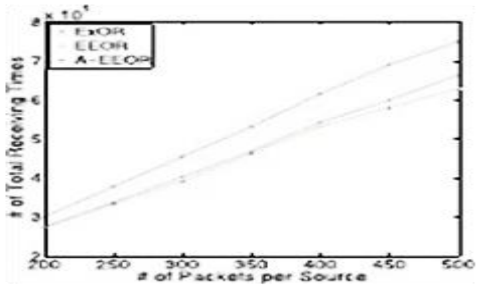

Fig 5 Net packets received with passage of time

In this study, we compared working of the scheme given in this paper, EEOR, with ExOR by comparing against metrics like rate of loss of packets, the usage of power, ration of duplicating of packets and packet transfer time from one end to the other end and back. To ensure a fair comparison, we used similar list of forwarders (maximum) in case of either schemes and set each batch to put in 1 packet for ExOR. We first compared the times of receiving and transmitting for every nodes of wireless type in case of either protocols, where we observed that the transmission and times of getting of ExOR were bigger compared to EEOR's due to two reasons: ExOR always chooses more nearby-nodes inside the list of forwarders towards a packet with a node's price expectation inside ExOR is dependent only upon the neighbors with the least ETX value, which is not as reasonable as considering the error rates of links from one node to those in the list of forwarder, as in EEOR. Subsequently, we gauged the overall energy utilization of both protocols employing the energy consumption metrics of the TmoteSky sensor node. Additionally, we selected 18 source/destination pairs in a haphazard manner within a consistent random topology for assessment. It was observed that the total energy utilization for each scheme increased with the information volume of each source node. In each scenario, the efficiency of our schemes surpassed that of ExOR. The packet loss rates in case of either protocols were compared by equating the information volume of every source point to five hundred, and eighteen pairs of sources/destinations were systematically compared one after another.

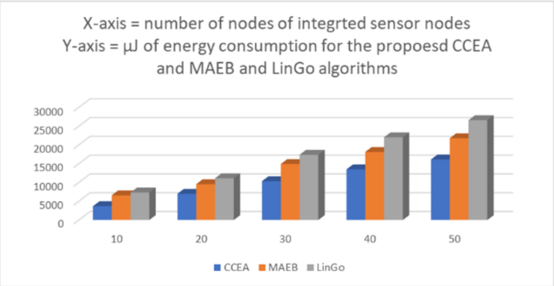

Fig 6 Evaluation of the proposed CCEA algorithm with respect to the MAEB [5] and LinGo [6] algorithm in terms of usage of power to send packets of information

From the results presented above it is evident that the with the increase in the size of the network the energy consumed by each one of the sensor node deplyment schemes like the CCEA, the LinGo [5] and the MAEB[6] increases.

Table 1 Energy consumption (in µJ/1 simulation cycle) data for packet transfer in case of proposed CCEA algorithms and its comparison with the LinGo and the MAEb algorithm.

Number of nodes →	**10**	**20**	**30**	**40**	**50**
Algorithms considered ↓					
CCEA	**3678**	**6993**	**10334**	**13471**	**16110**
MAEB [6]	**6573**	**9541**	**14894**	**18112**	**21768**
LinGo [5]	**7320**	**11104**	**17349**	**22005**	**26564**

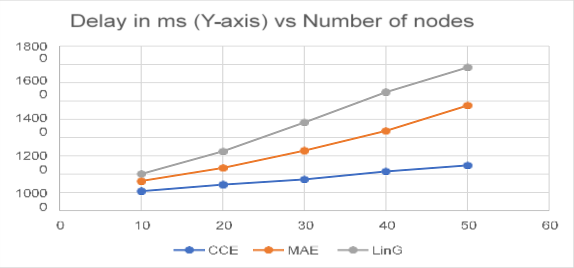

Fig 7 Change in delay in packet transfer (in ms) magnifying node-count in case of large networks

But due to the innovative algorithms for energy consumtion for the transmission of data packets using the CCEA algorithm is around 25% lower compared to the MAEB framework and about 40% lower compared to the LinGo framework. The graph in Fig. 7 gives us the delay in milliseconds of transferring data packets between the nodes of the IoT network and we have compared the delay obtained by the application of the proposed algorithm CCEA and compared its performance by the delay obtained by the application of the schemes presented in [7] namely MAEB and the scheme proposed in [5] namely LinGo. By the analysis we detect that the designed scheme of CCEA achieves much lower packet transfer delay compared to the other two algorithms. This makes the proposed algorithm more efficient than the other competing algorithms proposed in the literature. Incidentally other IoT based algorithms are also present in the literature that offers even lower delay values but their application and relevance in the specific area of designing of disaster-resilient theme parks is negligible.

Given above is the delay data presented in tabular form for network of size ten nodes, twenty nodes, thirty nodes , forty nodes and fifty nodes. All the data presented in the above mentioned table is measured in milliseconds. In the CEEA methodology, a changed iteration of the AHP or Analytic Hierarchy Process [9] is assumed to facilitate logical aspect of cognition within the Internet of Things.

Table 2 Packet transfer delay data for rising network size in the considered theme park

number of nodes →	**10**	**20**	**30**	**40**	**50**
Algorithms considered ↓					
CCEA	**2141**	**2864**	**3423**	**4299**	**4967**
MAEB	**3254**	**4672**	**6584**	**8744**	**11523**
LinGo	**4021**	**6503**	**9650**	**12980**	**15678**

In the realm of data path selection, AHP exhibits prowess in navigating the complexities of decision-making involving multiple criteria. When faced with scenarios demanding swift data delivery, AHP prioritizes the node with the minimal delay, even at the cost of compromising other metrics like network energy or throughput. Should two potential next-hops present identical delay metrics, the subsequent attribute under scrutiny becomes energy, followed by throughput, assuming energy stands as the next coveted attribute within the IoT network's framework. AHP introduces a methodical regimen for the pairwise evaluation of each attribute, facilitating the identification of a node poised to optimize the IoT network's long-term performance.

7.2 Code for the function on AHP for determining the paths by cognitive procedures

Function AHP (priorities of the attributes P)

Input

```
• P: End-user defined priorities on the attributes for requested data
• Output
• RNx: Forward-hop RNx{ RN1 ..... RNn} with best P
• Begin
• Initialize: priority matrix for traffic type; Success=0;
    ▪ 8. While ((z, X) ≤ r) > 0 in Eq. (5)
    ▪ AHP_analysis(Next-hop RNs v/s attributes)
    ▪ Next hop RN = RNx
    ▪ Transmit data to next-hop RN
    ▪ If (next hop = GCN)
    ▪ Success=1;
    ▪ Else
    ▪ Choose next-hop RN
    ▪ goto step 8
    ▪ End
    ▪ If (Success==0)
    ▪ GCN Retransmits request
• End
• End
```

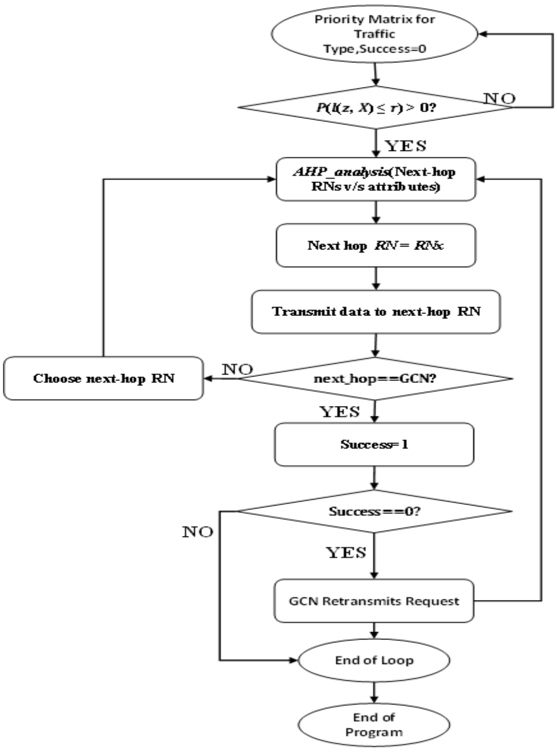

Fig 8 Flowchart for selection of paths using the Processes of Analytical Hierarchy (AHP)

The ensuing example provides additional insights into the employed AHP methodology. Embedded within the framework of CEEA lies the orchestration of AHP computations, not solely confined to immediate routing decisions but also serving as the architect of strategic foresight. The cognitive intricacies ingrained in the CEEA methodology bestow upon it the faculty to preserve computed values of IoT-network attributes, ensuring their seamless integration into forthcoming transmission iterations. This, in turn, obviates the imperative of recalculating these values with each successive transmission round.

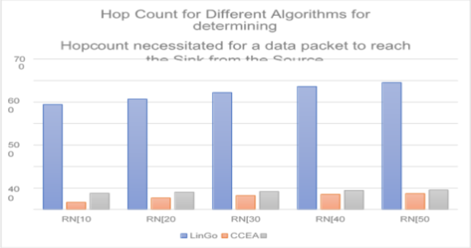

Fig 9 This bar graph gives us an analysis of the number of hops that would be necessary for transmission of packet towards the end nodes while starting from the first node during utilization of LinGo, MAEB and the proposed CCEA protocol.

The bar graph presented in Fig. 9 and the values enumerated in the table presented in Table 3 gives us an in-depth detailed analysis about how with the increase in the size of the network from 10 nodes to 50 nodes the changes that happen in the number of hops that has to happen in order for the generated packet to reach to the sink node from the source destination. From the graph the conclusion can be drawn that for the proposed network protocol of CCEA we neet to transfer much lesses number of packets compared to the other considered algorithms namely, MAEB and LinGo.

Table 3 Table displaying simulation results for number of Hops for transmission of data packets from source IoT node to the data Sink with the change in data packets

number of nodes→	**RN[10]**	**RN[20]**	**RN[30]**	**RN[40]**	**RN[50]**
Algorithms considered⇂					
LinGo	**489**	**514**	**544**	**573**	**591**
CCEA	**34**	**54**	**65**	**71**	**74**
MAEB	**76**	**81**	**84**	**89**	**91**

8. Conclusion

In conclusion, the paper proposed a new approach to mitigate workload imbalance in hazardous situations through mobile sink coordination. The proposed approach utilizes a mobile sink to coordinate the data collection process and balance the workload among static sensor nodes. The experimental results showed that the proposed approach outperforms the traditional data collection methods in terms of both workload balance and energy efficiency. The proposed approach also showed better scalability and adaptability to changing network conditions. Overall, the proposed approach provides an effective solution to mitigate workload imbalance and improve the performance of data collection in hazardous situations.

Author contributions

Arati : Conceptualization, Methodology, Software, Field study, Data curation, Writing-Original draft preparation, Software, Validation., Field study. **Dr. Manoj Patil:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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