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Issues, Challenges and Techniques in WSN for Performance Enhancement in Underground Coal Mining

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Abstract- Recently, technological growth has gained huge attraction and it is widely adopted in various real-time application systems/ this increasing growth has improved the communication technology by developing small and tiny sensors for information gathering and transferring by consuming less energy in real-time systems. These type of sensor systems are known as wireless sensor network which are used widely in real-time applications such as environment monitoring, traffic monitoring and bio-medical applications etc. In this work, we have focused on the coal-mine monitoring system which can provide the security for mine workers. Mine monitoring systems require an automated process to obtain the information about mine-roof and its convergence along with time which can be used for safety of miners or workers. In order deal with this, wireless sensor network based study is considered as base application.

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Issues, Challenges and Techniques in WSN for Performance Enhancement in Underground Coal Mining

Banda Srikanth [a], Dr. Hemant Kumar [b], & Dr. K.U.M Rao [c]

Abstract- Recently, technological growth has gained huge attraction and it is widely adopted in various real-time application systems/ this increasing growth has improved the communication technology by developing small and tiny sensors for information gathering and transferring by consuming less energy in real-time systems. These type of sensor systems are known as wireless sensor network which are used widely in real-time applications such as environment monitoring, traffic monitoring and bio-medical applications etc. In this work, we have focused on the coal-mine monitoring system which can provide the security for mine workers. Mine monitoring systems require an automated process to obtain the information about mine-roof and its convergence along with time which can be used for safety of miners or workers. In order deal with this, wireless sensor network based study is considered as base application. This article presents various recent approaches which helps to improve the wireless communication system such as energy aware routing, wireless sensor network localization etc. A comparative study is presented based on these aspects of wireless sensor network which shows that still the performance of WSN can be improved which can be incorporated with coal-mine monitoring system.

Keywords: coal mining monitoring systems, WSN, localization, routing.

I. Introduction

Due to the problems like aeration, ventilation and chances of collapse, underground coal mining generally consists of greater threats compared to open pit mining. Nevertheless, use of heavy machineries as well as techniques which are executed for excavations purposes resulted in safety hazards in all any kind of mining. Significant changes in mining and progresses in safety level in both underground and opencast mining can be implemented, because modern mines now use numerous safety measures, training as well as education for labors along with good health and safety standards. In India, "coal" has a considerable influence on rapid industrial expansion of the country. It is considered as one of the major resource of energy.

The significance of coal in the sectors like energy is very crucial, as about 70% of power generation relies on it. On the other hand, supplementary by-products of coal, which are proven as a potential threat to people who are associated with it, and also to the environment. So, the present work makes an honest attempt in examining the severity of mining, as well as inventing real time monitoring system for detection of life threatening situation, through 'ZigBee technology'.

It is necessary to deal with non-lethal and non-dangerous environments, and also to adopt an operational working mine, air circulation systems, etc., are very critical to provide sufficient level of oxygen in case of underground mining [87]. Controlling an underground mine simply means destroying hazardous environments. For monitoring a mine's air, we are still using the conventional techniques like, consumption of canaries and also varieties of creatures to warn diggers about the harmful turn of climate. With the help of far reaching statistics obtained by monitoring system, combining ventilation monitoring system will permit a mine to insightfully establish ventilation improvements. Drastic variations, speedy deviations in ventilation systems are picked up by monitoring system. To handover the data to the surface and to supervise mines more competently, one can use new as well as innovative communication methods.

Mine monitoring techniques have become more cultured due to development of technology. But however demolitions in the underground coal mines will take place even today. A major challenge for the nation and for society is nothing but the safety concerns of coal mines. Unpredictability of the working condition and also harsh environment are the main reason for tragedies in coal mines. Hence, for safety purposes, enactment of the mine monitoring systems becomes vital. As a trend, wired network systems are used in coal mines, which has played an important role in safe production. Several unforeseen hazards are hidden with constant elaboration of exploiting area and also with depth expansion. In other words, it can be said that these issues have become blind zones.

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In addition, it is not imaginable to place dedicated cables, as it requires more time. Therefore, in order to carry out a safe production, it is crucial to build a WSNs mine monitoring systems. At the moment, Wireless sensor networks (WSNs) have got a substantial worldwide attention. A self-organizing, multi-hop and special ad-hoc network which contains huge quantity of nodes, which are organized in a wide area to monitor the occurrences of interest, is known as wireless sensor network. It can be used for many applications such as environmental, scientific, military and medical applications. WSNs primarily contain motes or sensor nodes which are accountable for identifying an occurrence and also base nodes, which are liable for handling network and gathering data from the remote nodes. Operation mechanism, scalability, sensor network topology, fault tolerance, transmission media, power consumption and hardware constraints, etc., are some of the main factors which are directly influencing the design of the sensor network.

The three foremost benefits over wired monitoring network systems are given bellow:

1. Installation is very easy in the blind areas and cables are not needed to set up the network, which decreases the cost of monitoring system. To reduce blind areas, quantity of nodes can be increased. Moreover, it provides reliable communication, as well as fulfilling the objective.
2. The remote monitoring system makes perfect sense for such scenario, due to its limited storage ability and limited computation capacity. As a result, wireless sensor network becomes suitable for scrutinizing safe production in coal mines.
3. Ideal data communication and data procurement with the high accuracy and advanced recognition of a real-time monitoring system which are designed for mine atmosphere, can be ensured by the dense nodes.

Mining atmospheres always have unseen hazards, toxins, which may create many health-related issues to people who are working in the mines, and also on the outside too. On a timely basis, these toxic gases must be detected and raise an alarm about the hazardous situations without any delay for safety of miners. Additionally, limitation of mining walls may also trigger massive harm. Therefore, endless monitoring may help reduce the risk to miners.

Wired network monitoring systems is not perfect for all forms of mining atmosphere, even though it substantially helps in improving the mine safety. For controlling and monitoring the mining atmosphere, Real-time monitoring systems can be used. Zigbee technology is perfect for real-time monitoring system, due to its numerous benefits. Hence, designing an efficient monitoring system is the major objective of this proposed work, by which several leaked mine gases and also other features like pressure and depth etc. can be recognized at regular intervals and protective actions can be implemented consequently.

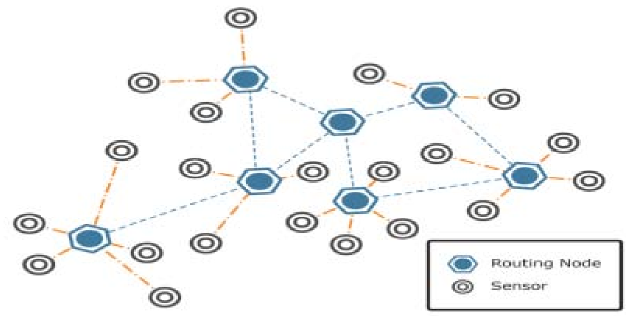

Figure 1: Wireless Sensor Network

This proposed work emphasizes on wireless sensor monitoring scheme which are designed for coal-mine monitoring system. A number of designs has been proposed for wireless monitoring system for external atmospheres. Nevertheless, it still poses a big challenge for the underground circumstances, like coal mining. Underground coal-mining systems undergo several serious problems, which might lower the monitoring power. Such problems are given below:

a) *WSN Routing*

Routing in the WSNs is a vital task for data diffusion. Wireless sensor networks (WSN) nodes are driven by inadequate resources of energy. Therefore, more energy utilization might result in degradation of overall lifetime of the network. Likewise, packet drop and security problems also occur in Wireless sensor networks communication system, if the links are not connected accurately, and effective routings are not applied.

i. *Wireless Sensor Localization*

Performance of coal-mining monitoring system can be improved by a well-organized method for Wireless sensor networks localization. Improper or inadequate data for monitoring may be resulted, if the nodes are not positioned at the precise location.

ii. *Wireless Sensor Network Localization*

Localization in WSNs was one of the vital modules of variety of developing solicitations together with the cyber-physical systems, military [1], Health [2], atmosphere monitoring, house and workplace automation, weather projecting[3]etc. Location based services are needed for many of above mentioned applications. The high power consumption, high price, and poor presentation of GPS within indoor environment have demanded the study on localization algorithms, even though the GPS was a direct solution to the localization problem. In recent years, the technical world has witnessed a lot of studies efforts on this subject. It should be noted that localization is termed as determination of location of unknown node, by using the connectivity information between the unknown nodes and at other times, assistance of nodes with known point.

Latest surveys have studied the influence of the real world applications [4], movement in localization [5], “Anchor Free" and “Anchor Based" localization techniques [18], distance dimension method which is used to analyze the location of unknown nodes (“Range Based" localization algorithm) and “Range Free" localization procedure (connectivity instead of distance) [6], “Cooperative" (communication present between all nodes) and “Non-Cooperative" (communication between unknown nodes and anchor nodes) techniques, “Centralized" localization (aka network-centric positioning [7]) and also “Distributed” techniques (in which there is no vital control on determination of node’s location and every node calculates its location based on the locally collected data, also termed as “self-positioning" algorithm [7]).

In this segment, localization systems/techniques in wireless sensor networks are classified into “Anchor based vs. Anchor free", “Sparse vs. Dense", “Indoor vs. Outdoor", “Static vs. Mobile", and “Cooperative vs. Non Cooperative” categories as presented in Fig. 2. And, to describe each system, based on the altered aspects like, whether they are distributed or centralized and non-cooperative or cooperative, etc., comparison tables are presented at the end of the anchor free and anchor based localization system units.

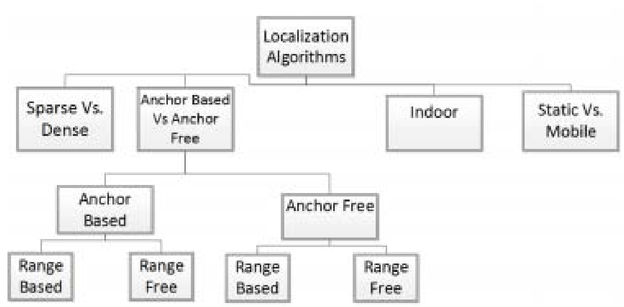

Figure 2: Typical classification of localization techniques in WSNs

Wang et al. [9] studied about WSNs localization system and also the problems related to the same. For the network operators it is noticeable that sensor node location information is very critical and therefore GPS based localization systems are used. Han et al. focused on significance of wireless sensor network localization system[10]. Meanwhile, as it offers vital provision for many location-aware procedures and applications, Localization has become the key technologies in WSNs (wireless sensor networks). Mao et al. conducted a detailed study on fixed localization in WSNs [11]by paying attention to various aspects such as single hop, multiple hop, centralized and also distributed. The study is comparatively older and it does not deliberate on the mobility concerns of sensor network. Also, there is a scarcity of recent mechanisms in the field, as well as conversation on open problems and investigation experiments. A study was conducted by Faheem et al. [12] on data broadcasting of the mobile sink in by categorizing the data broadcasting procedures based on routing entities, mobility pattern, quantity of sinks and application type.

Dong et al. in conducted a survey on issues of mobility and also mobility conscious MAC (medium access control) practice in WSNs [13]. The authors have contemplated on diverse mobility forms and prototypes, advanced mobility valuation approaches, and also complete and relative examination of projected mobility-aware MAC procedures. The review highlights only the mobility parameters and MAC procedures of WSN, instead of the localization in WSNs. Han et al. in [14] presented a survey on localization in WSNs. The authors have considered numerous procedures which are based on the fixed and mobile nodes and on range free and range based techniques. It was published in 2013, and hence it is one of the latest surveys of the localization algorithms. But, it did not include any further investigation, nor it offers suggestions for future research enhancements.

Mesmoudi et al. undertook a detailed survey on localization procedures [15]. The procedures are principally categorized into range based and range free systems, and both are additionally categorized into hybrid schemes and full schemes. This survey grants a complete study on the procedures, but it omits the mobility issues. Gu et al. in [16] has conducted a latest study on the sink mobility management along with current research developments. But, it failed to deliver source localization, and hence arrangement and comprehensive conversation of localization procedures are not found. On the basis of these studies, a comparative investigation is made, which is shown in the table 1.

Table 1: Related WSN localization techniques

Survey paper	Main aim of study	Mobility based research	Survey coverage type	Concluding remark
Wang et al. [9]	WSN localization	No	Comprehensive	Presented latest techniques in WSN localization
Han et al. [10]	Localization	No	No	Presented anchor based WSN localization
Faheem et al. [12]	Data aggregation	Comprehensive	Yes	Presented data aggregation scheme
Mao et al. [11]	WSN localization	No	Comprehensive	Presented Static localization scheme for WSN
Dong et al. [13]	MAC protocol	Comprehensive	Comprehensive	Comparative study on MAC protocols
Tunca et al. [29]	Sink routing scheme	Comprehensive	Comprehensive	Survey on sink routing schemes
Mesmoudi et al. [15]	WSN localization	Restricted	Comprehensive	In-depth discussion on WSN localization
Han et al. [14]	Localization	Comprehensive	Comprehensive	Mobility based classification of sensor nodes
Gu et al. [16]	Sink mobility	Comprehensive	Comprehensive	Presented Sink mobility management
Ours	Routing & Localization	Comprehensive	Comprehensive	Presented localization and routing techniques for WSN

In addition, a transitory conversation is presented about numerous types of localization techniques, as shown in the figure 2.

b) Sparse and Dense WSN Localization

Two types of techniques had been introduced in the past to deal with sparse network: they are, component based localization and node based localization.

i. *Node based localization*

Sweeps' is a node based localization scheme [17] which is associated with iterative technique, known as 'trilateration'. In trilateration system, a coordinate system is defined on the basis of a major set of three nodes with the fixed location information. At every phase of algorithm, there will be the set of finitely localized nodes, in which nodes can be regulated up to a fixed set of potentials, and also a set of un-localized nodes. Huanxiang et al. [18] studied about localization and also about its benefits in WSN and localization scheme, on the basis of genetic algorithm for the mobile anchor node. Based on the distance from anchor node to unknown node, as calculated by RSSI, the algorithm pools genetic algorithm and weighted centroid method to locate the unidentified nodes.

According to Jiang et al. [19], foremost idea in the most localization algorithms of present day WSNs, is that a mobile anchor node, for instance the GPS-equipped (Global Positioning System) nodes, which shows its location information to discover unidentified nodes. In that case, one basic problem was the path planning of mobile anchor node, which must and should move along its route to lower localization blunder and to discover the unidentified nodes. Han et al [20] proposed a research study for WSN localization, based on distributed localization method and presented NDBL (node distribution-based localization) scheme. Low system-load for low-cost, simple modification and low-rate wireless sensors, are main objectives of this method.

ii. *Component based localization*

In component based technique, a factor or elements consists of a set of nodes which are termed as components. These components establish a globally inflexible structure in the distance graph. Due to the rigidity of the structure, the location of each node in an element is static. In comparison to node based localization algorithm, component based localization scheme easily detects two dimensional components. Component based localization can be categorized on the basis of the existence of internal anchor in a component.

c) Anchor based vs. Anchor Free Localization

With respect to use of location data of the known nodes, the localization based techniques are categorized as "Anchor Free" and "Anchor Based" systems. Details of these algorithms are presented in subsequent sections.

i. *Anchor based Localization*

In anchor based localization method, few nodes are known as anchors, which are embedded with a GPS

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module that offers global position for these nodes. Nodes with the unidentified locations gather data from anchors to predict its locations by self-localization.

This data might point out the distance capacity or about the connectivity which distinguishes distinct two diverse subclasses of the anchor based localization: “Range free” and “Range based” localization systems. This schemes uses several algorithms such as, conversed anchor based systems [21-25]least square, [26-30] extreme likelihood assessment, [31] lateration system, [32] the multi-dimensional scaling, [33] the semi-definite encoding, [34] [56] supernatural regression, [35]fingerprinting, and [36] the Monte-Carlo localization for localization of the unidentified nodes.

a. *Range based Approaches*

Range based localization system with MDS was presented in ref. [32]. In this method, the iterative MDS and classical MDS are used to generate local maps of neighboring sensors. To compute the location of the sensors, MDS uses the pairwise distance between nodes, and iterative approach is implemented, when the spaces between the node pairs are unobtainable. Range based maximum-likelihood (ML) scheme was presented by O˘guz-Ekim et al. recommend [33]. The primary idea of this algorithm is to create a source localization technique by building a ML valuation problem which will be followed by convex relaxation of ML by SDP.

Yaghoubi et al. [22] recommended Energy-efficient range based localization. In this method, average energy of received anchor will be presented as new decision-making parameter for the localization. Localization scheme was presented to display the correlation with power distribution of anchor nodes. Two cases are deliberated accordingly: localization presuming error free anchor nodes location, and localization which considers erroneous anchor nodes location. With the help of mathematical calculation, it is confirmed that localization correctness can be controlled by variable power provision of the anchor nodes. Simulation outcomes show that optimal power allocation outperforms equal power allocation, as confirmed by mathematical analysis of both erroneous and error free conditions. Range based localization pattern which reflects a Bayesian approach was proposed in ref. [6]. As a replacement for a conventional path loss model, this effort presents a ranging measuring scheme by means of a Bayesian model. To develop a system which requires a reduced amount of prior information, ‘Empirical Bayes’ methodology is used in this research. The benefit of this ‘Empirical Bayes’ is that it needs fewer conditional prior information. Some conditions are applied to discover Bayesian estimation more precisely. In this technique, MMSE (minimum mean square error) estimator was determined for final valuation as provisional mean.

b. *Range Free (non-range based) Approaches*

Range free localization scheme utilizes connectivity data among nodes to regulate the points of unidentified nodes. As the range based approaches need a hardware arrangement, which is both costly and complex, a range free method will be a possible solution. In this section, a recent anchor based range free localization algorithm is discussed.

Wang et al. [37] presented a range free localization system as an enhancement to conventional DV-Hop procedure. The concept of regulated neighborhood distance (RND) had been discussed in ref. [38], by means of disk communication system for localization. The notion of RND is reconsidered and restored with an effort implement RND in general propagation model. Fixing the problem of hop-distance uncertainty by computing the closeness of two neighboring nodes is one of the main purposes of the RND system. The approximation of the location of an unidentified node is estimated using Trilateration system, after the spaces from three anchors to unidentified node are computed. An area-based localization system was presented by Lasla et al. [39], in which a novel method half symmetric lens (HSL) was proposed.

Non-localizable node may determine its location in a given area by making a comparison on the received data from various anchors. In order to evaluate the performance, this technique has been compared with APIT, circular based system DRLS [40] and ROCRSSIA, by considering evaluation error and the ratio of the localizable nodes, as matching factors. Ratio of localizable nodes are termed as the proportion of nodes precisely situated at certain location in the area, and also evaluation error is termed as the difference between actual and projected distance of the node. Simonetto et al. presented a Maximum likelihood distribution localization scheme [28]. An ML based convex relaxation scheme is presented in this paper, with comprehensive explanation of its features.

With respect to above mentioned techniques, a comparative study is presented for anchor free localization algorithms, as shown in table 2.

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Table 2: Anchor free localization algorithms

Algorithm	Range Measure	Range combinations	Localization method	Scalability	Node density	Cooperation	Localization accuracy	Node mobility
X. Ji et al. [32]	RSSI	MDS	Distributed	Yes	Medium	Cooperative	Medium	No
Y. Xu, [21]	RSSI	LS	Distributed	Yes	Medium	Non-Cooperative	Medium	No
Yaghoubi, et al. [22]	RSSI	LS	Distributed	Yes	Medium	Non-Cooperative	Medium	No
Oguz-Ekim et al. [33]	ToA	SDP	Central	No	Medium	Non-Cooperative	High	No
F. Bandiera [41]	RSSI	MLE	Distributed	No	Medium	Non-Cooperative	High	No
Tomic, [8]	RSSI	LS	Central	Yes	Medium	Non-Cooperative+ Cooperative	High	No
Dranka et al. [26]	Acoustic	MLE	Central	Yes	Medium	Non-Cooperative	High	No
Shen et al. [24]	ToA	LS	Central	Yes	Medium	Non-Cooperative	Medium	No
Coluccia et al. [6]	RSSI	ILS	Central	Yes	High	Non-Cooperative	Medium	No
Gepshtein et al. [34]	Connect	SR	Central	Yes	Medium	Cooperative	High	No
Yin, et al. [27]	ToA	MLE	Distributed	Yes	High	Cooperative	Medium	No
Nguyen et al [25]	NS RM	LS	Distributed	Yes	High	Cooperative	Medium	No
Salari et al [42]	RSSI+ToA	MLE	Distributed	Yes	Medium	Non-Cooperative	Medium	Yes
Wang et al [43]	Connect	Trilat	Distributed/ Central	Yes	High	Cooperative	High	No
Jean et al. [29]	ToA	IML	Distributed/ Central	Yes	Medium	Non-Cooperative	Medium	No
Lasla, et al [39]	RSSI+ connect	RA	Distributed	Yes	Medium	Non-Cooperative	High	Yes
Simonetto et al. [28]	Connect	MLE	Distributed	Yes	Medium	Cooperative	Medium	Yes
Diao,[31]	NS	Trialt	Distributed	Yes	Medium	Cooperative	High	Yes
Mourad [35]	RSSI	FP	Distributed	Yes	Low	Non-Cooperative	High	Yes
Huang et al. [36]	RSSI	MCL	Distributed	Yes	Medium	Non-Cooperative	Medium	Yes
Akba et al [44]	Connect	Multial	Central	Yes	Medium	Cooperative	Medium	Yes
Khan et al [45]	RSS + AoA	Trialt	Central	No	Medium	Non-Cooperative	High	NO

ii. *Anchor Free Localization*

Anchor-free localization techniques do not any location information of the nodes to determine the location of unidentified nodes. Such techniques have liberty on orientation and translation. On the basis of the usage of the range measurement methods, these localization techniques can be classified into two categories, range free anchor free and range based anchor free. Anchor free localization techniques do not need any complex anchor selection process. In the preceding topics, anchor free localization techniques of range free and range based types are presented.

Table 3: Anchor free localization scheme

Algorithm	Range combinati-ons	Range Measure	Localization method	Node density	Scalability	Node mobility	Cooperation	Localization accuracy
Savarese, [46]	Triang	RSSI	Distributed	High	Yes	No	Cooperative	High
Priyantha, et al. [47]	Multilat	Acous+Con nect	Distributed	Medium	Yes	No	Cooperative	Medium
Moore et al. [48]	Trilat	TDOA	Distributed	Medium	Yes	Yes	Cooperative	Medium
Shang et al. [49]	MDS	Connect	Centralized	Medium	No	No	Cooperative	Medium
Shang et al. [50]	MDS	Connect	Distributed	Medium	No	No	Cooperative	Medium
Kwon et al. [51]	Multila/MDS	Connect	Centralized	High	No	No	Cooperative	High
Kwon et al [52]	Multila/MDS	Connect	Centralized	High	Yes	No	Cooperative	Medium

II. Issues And Challenges In WSN Localization Schemes

Based on above observation, numerous researches have been carried out in WSNs to introduce and implement new algorithms for localization in WSNs. Such techniques can help reduce effects caused by inaccuracy in the distance measurements and locations of the sensor nodes. Nevertheless, few issues still require more intense study, in order to enhance the localization in the WSNs. Few of such issues are given below:

a) *Efficient Energy Consumption in Wsns Localization*

Typically, the sensor nodes in WSNs are equipped with restricted power source and unchangeable batteries or other energy supplies. This makes them work for a limited amount of time, before they die of energy depletion. Energy consumption is foremost design challenge in numerous WSN applications [53]. Although several researchers have presented numerous energy efficient localization scheme for WSNs, they are still not entirely powerful, and the design challenges with respect to energy consumption is still prevalent.

b) *Localization in 3D WSNs*

Generally, localization in WSNs focuses on determination of location of the sensor nodes in a two dimensional region. Ref. [9] suggests that, few applications require 3-dimensional distribution of node, such as survey underwater ecosystem, environment monitoring, surveillance of terrains, space monitoring and exploration, etc. Because of such complexities, the localization becomes harder, and hence more research has to be done for localization of node in three dimensional (3D) WSNs. Three dimensional (3D) localization techniques are highly complex. It is challenging for the sensor nodes to get the ranging and location measurements, because of irregular topologies and non-uniform densities. In comparison two dimensional WSNs, the three dimensional WSNs have fewer localization schemes. Limited research is available in this regard, [54].

c) *Localization in Mobile Wireless Sensor Networks (MWSNs)*

The WSNs have numerous challenges, among which maintenance of connectivity and boosting the lifetime of the network, are most significant. These challenges can be addressed by integrating the mobile device in WSNs [91]. Moreover, the network coverage and connectivity can be enhanced by mobility, along with better tracking capability of mobile nodes [55]. In mobile WSNs, localization is a major challenge. In traditional static WSN, the locations of sensor nodes are fixed, unlike MWSN, where the nodes tend to roam freely about the given region. Hence, they have to periodically update their location information [55]. As a result, mobility in WSNs has drawn more interest from numerous researchers. In ref. [55], the researcher has presented few proposals to enrich the location in MWSNs, as given below:

- Implementation of better distributed localization algorithms.
- Minimizing the location latency without affecting the accuracy of location.

- Implementation of novel algorithms to extend the mobile sensing to the regions where data sensing in not safe/secure.

d) Secure Localization

One of key challenge in widely deployed WSNs, is the secure localization. Normally, the WSNs are implemented in a hostile environment. But, the localization technique is susceptible to numerous localization-specific attacks. Over the years, this topic on issues of secure localization in WSNs is gaining more interests from numerous researchers around the world. But there is still room for improvement. In ref. [56], the authors have discovered few parameters, which can contribute to secure localization process. They are given below,

- Secure localization algorithms for mobile sensor nodes
- Range-free based algorithms for Verification of localization
- Localization in un-trusted environment
- Keeping the location information of node, confidential, without hindering inter-node communication.

e) Error Propagation in Interferometric Ranging based Localization

A ranging Technique has been presented based on Radio Interferometry, for localization in WSNs [57]. The measurement can be precise in comparison to other general localization techniques, like Time of Arrival (ToA), Received Signal Strength (RSS), and Angle of Arrival (AoA). However, it turns out to be harder, as higher measurement readings are needed, and hence, this technique is restricted to smaller networks with less than 16 nodes [58].

III. Wsn Routing

Over the previous decades, comprehensive research was conducted to resolve the issues of cooperation between sensors in information aggregation and handling, administration and coordination of the information sensing, etc.

In comparison to wired networks, due to inherent characteristics of WSN, such as wireless communication (MANET, Cellular network, etc.), routing becomes a challenging task. First, it is not sensible to generate universal addressing methods for sensor nodes, as the amounts of sensor nodes in WSN are high. This imposes the overhead of maintaining the ID of each sensor. The IP (internet protocol) will also fail to provide suitable solution to WSN applications. In case of ad hoc networks, the sensor node must be able to configure and govern themselves, without any intervention from network engineer or any other management system.

Second, compared to typical communication networks, any type of applications using sensor networks needs to transmit the collected information from multiple sources to other destinations or base stations. Third, the sensor nodes have limited resources, such as low processing power, low energy, limited storage, etc. Hence, the operation of network must be carried efficiently. Fourth, sensor nodes generally are static in most WSN application, except for few application involving mobile nodes. The application which permits random movement mobile nodes, are more arbitrary and unpredictable. They are harder to manage, as the network topology changes quite frequently. Fifth, sensor networks are application-specific, which suggest that, each different application require different design approaches. Sixth, it becomes essential to know the current location of sensor nodes. Lastly, data collection in WSN is performed using common procedure, which might result in data redundancy. The redundancy must be addressed using routing protocols to enhance network lifetime and energy saving.

a) Routing Protocols in WSN

A survey of few advanced routing protocols for WSNs are presented in this section. The routing protocols in WSNs are broadly classified into, hierarchical-based routing, flat-based routing, and location-based routing, based on the network structure. In hierarchical routing, the nodes assume various roles in the network. In flat-based routing, every node is assigned with identical functionality or roles. The location-based routing uses locations of the sensor nodes to establish routes in the network. When certain parameter of the routing protocols can be regulated for adapting to present network criteria, then they are considered as adaptive. They are adaptive to energy level of the node too. Accordingly, such protocol can be categorized into query-based, multipath-based, QoS-based, negotiation- based, and coherent-based routing algorithms, based on the protocol operation.

Apart from aforementioned categories, the protocols can also be categorized with respect to the mechanism of finding a route from source to destination. Based on this criteria, the protocols are classified into, reactive, proactive and hybrid algorithms. In reactive algorithms, the routes are established on-demand. In proactive protocols, the routes are pre-computed before they are used. In hybrid protocols, both reactive and proactive algorithms are combined for more efficient approach. In case of static sensor nodes, table-driven routing protocols are more effective than reactive protocols. In order to initiate reactive protocols, large amount of energy is needed. There is another set of routing protocols, known as cooperative protocols. In this routing protocol, the nodes forward the data to a central node. The central nodes collect all the data and perform certain processing operation, which lower the cost of routing and energy utilization. Timing and position information are important for several protocols. A brief discussion is also made on such protocols.

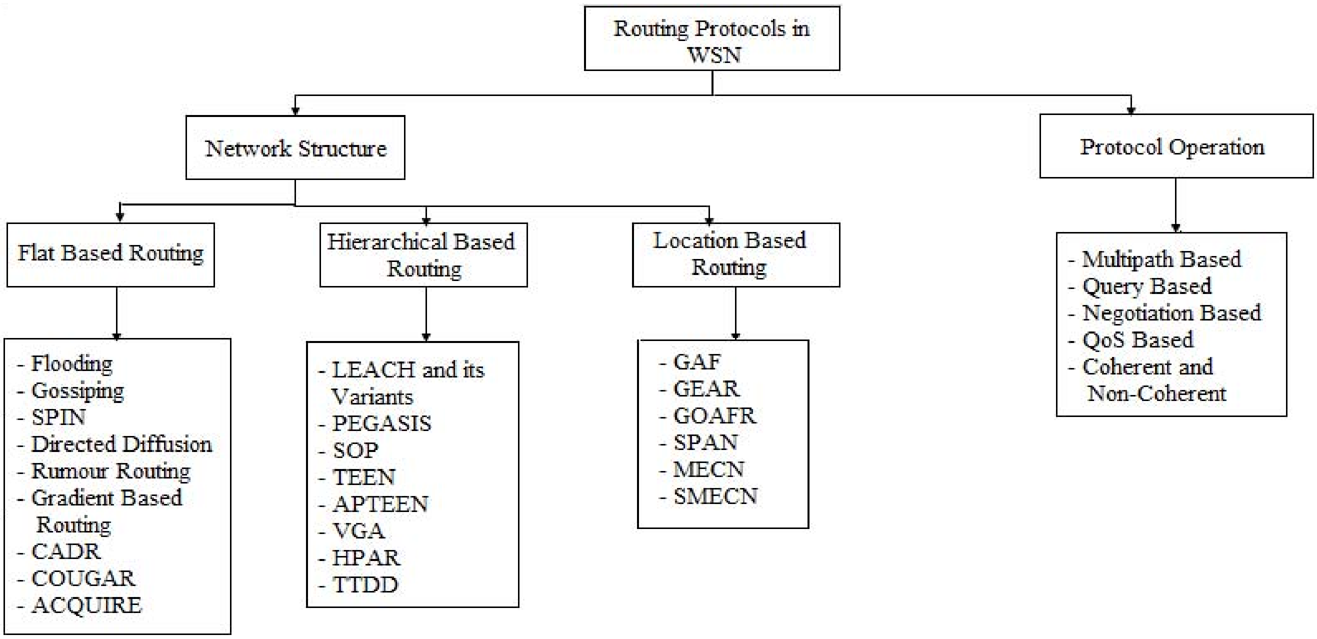

Figure 3: Classification of routing protocols

- *Flat Routing*

The multihop flat routing protocols are the first category of routing protocols. In flat networks, every node performs the same task and sensor nodes join each other to sense the environment and pick up the data. Assign a global identifier to each node is not always possible, due to large number of nodes. This resulted in data-centric routing, in which, the base station transmits the queries to particular areas and waits for data from sensors in that area. As queries are used to request for data, attribute-based naming must be used to identify the properties of data. The general classification of routing protocols is shown in figure 3.

- *Flooding and Gossiping*

The researchers presented a group of adaptive protocols in this category, namely, Gossiping and Flooding [59][103]. The data can be relayed in sensor networks using two classical methods, without any help of complex routing algorithms or topology maintenance. The image in Fig.4, depicts the concept of flooding, where each node broadcasts the packet after receiving it. The packets will be circulated to all of its neighbors. This process does not consider the capabilities of nodes. This process is will be terminated once the packet reaches its destination, or maximum number of hops for the packet is reached.

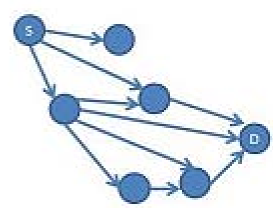

Figure 4: Flooding

Nevertheless, this protocol has few disadvantages, which are, overlap, impulsion and resource blindness. Therefore, the gossiping technique follows an entirely different approach. Rather than flooding the entire network with the data packets, the nodes transfer the packet to one of its neighboring nod only.

- *Sensor Protocols for Information via Negotiation (SPIN)*

Sensor Protocols for Information via Negotiation (SPIN) is a data centric routing protocol, which belongs to flat routing protocols [60]. It is based on negotiation model, which is used to forward the data within the WSN. This protocol solves the problems faced by flooding technique by negotiation and resource adaptation. This algorithm considers every node as a sink and transmits data to all the nodes in the network.

The SPIN works on two basic concepts [61]: Sensor nodes exchange information or brief details about the date before sending the data itself. In this way, the node can check if the data is already received or if it requires the new data packet. Such description can be exchange using meta-data of the information. Thus, redundancy can be kept under check. Every node has the ability to manage its own energy resources. This helps in energy efficient performance and extension of network lifetime. SPIN exploits three operation stages, namely ADV (Data Advertisement), REQ (Request for Data), DATA. The operation is shown in Fig 5.

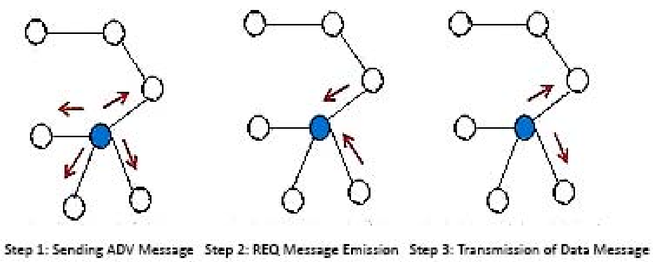

Figure 5: SPIN Protocol

- *Directed Diffusion (DD)*

Directed diffusion (DD) [61]is a well-known data aggregation model in WSNs. It was initially introduced by C. Intanagonwiwat et al. in 2000. It's a data-centric routing algorithm with data propagation schemes. Application-sensitive model uses on-demand data query and forwards data to concerned target for proper delivery. The data generated by sensor nodes are named by attribute-value pairs, such as interval, objects, geographical area, and duration. These data can be utilized for the description of the information. The process is depicted in Fig.6.

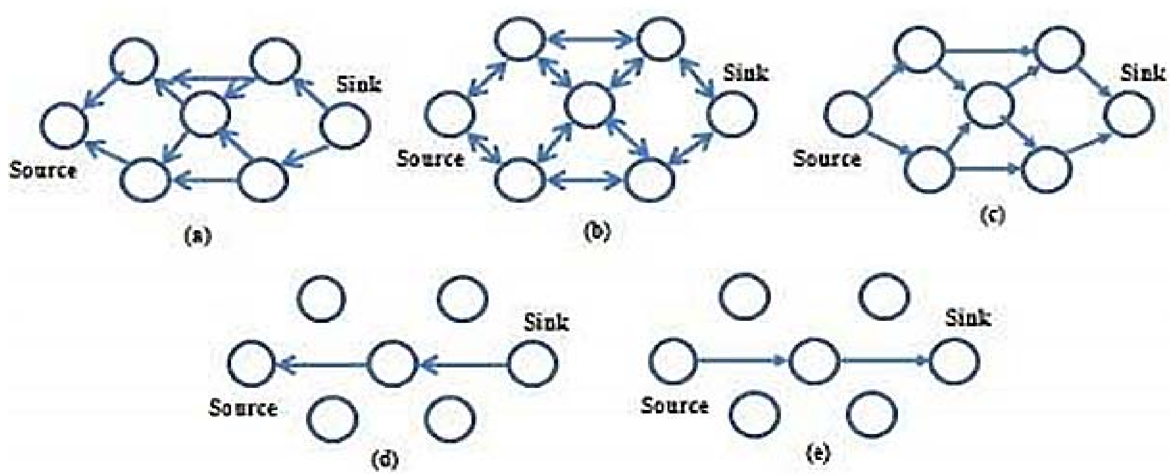

Figure 6: a- Broadcasting interest b-Establishment of gradients c- Data propagation d- Selecting and reinforcing path e- Transmitting data

- *Rumor Routing (RR)*

Rumor Routing (RR) [62] is a type of Directed diffusion technique. It was first presented by Estrin and Braginsky in 2002. It was proposed for those networks, which did not support geographic routing. In this protocol, the packets will be transferred to nodes which have triggered an event, instead of flooding the whole network with data packets. The Rumor Routing adds the event to a table whenever an event occurs at a node. This table is known as events table. Later, the protocol creates an agent, which is nothing but a data packet with long life. It can cover a greater distance in the network. In case if a shorter path is discovered to an event, then the protocol updates the table with the new path. If a node creates a query for an event, then other nodes which are aware of the path in question, will reply to this query. If none of the nodes known the path, then the query is sent in random direction.

- *Gradient-based Routing (GBR)*

An enhanced version of Directed Diffusion was presented by Schurgers and Srivastava, in 2001, which was known as Gradient-Based Routing (GBR) [63]. This routing scheme consists of hop-count (number of hops) when the query is disseminated in the network. The essential concept of GBR is to select the shortest path with lowest hop-count to the destination. This parameter can be calculated for each node, and it is termed as height of the node. The difference between a height of a node and its neighbor is known as gradient. The packet will be sent to the path with highest gradient. For the purpose uniform distribution of traffic in the network, traffic spreading techniques are used with GBR. When a node behaves as a relay, then multiple path will cross this node. In such situations, the concerned data will be aggregated. GBR can be used with various data spreading techniques, such as, Energy-based scheme, Stochastic Scheme and Stream-based scheme [64].

- *Cougar*

COUGAR [65] was first presented by J. Gehr and Y. Yao in 2002. It is information driven routing convention. It was designed with an intention to address the issues with large distributed database systems. The principal concept of this schemes is to present a fresh query between the sensor network and applications. This layer makes use of declarative queries to extract query processing from the network layer functions. This includes selecting applicable sensors and use in-network data aggregation to conserve energy.

- *Active Query Forwarding in Sensor Networks (ACQUIRE)*

Dynamic Query Forwarding in Sensor Networks (ACQUIRE) [66] technique is presented by Sadagopan et al. in 2003. It is used for querying sensor nodes. This protocol considers the networks as a distributed database, just like COUGAR. This technique is appropriate for complex inquiries which are composed of few sub queries that might be addressed enroute. The main rule of ACQUIRE is to presume the query as a dynamic object, which is sent within the network seeking for a possible solution [67].

The characteristics are presented in table 4, based on the comparison of flat-based routing protocols.

Table 4: Flat-based Routing Protocols

Routing scheme	Category	Mobility	Scalability	Data aggregation	QoS	Multi-path	Power Consumpt-ion	overhead	Query	Data Delivery modeling
Flooding	Flat	Limited	No	☒	☒	✓	Excess	High	☒	☒
Gossiping	Flat	Limited	Limited	☒	☒	☒	Excess	Moderate	☒	☒
SPIN	Flat/Data centric	No	Limited	✓	☒	☒	Limited	Low	✓	Event based
Direct Diffusion	Flat/ Data centric	No	Limited	✓	☒	✓	Limited	Low	✓	Demand based
Rumor routing	Flat	Limited	Good	✓	☒	☒	Low	Low	✓	Demand based
Gradient Based routing	Flat	Limited	Limited	✓	☒	☒	Low	Low	✓	Hybrid
CADR	Flat	No	Limited	☒	☒	☒	Low	Low	✓	Continuous
COUGAR	Flat	No	Limited	✓	☒	☒	Limited	High	✓	Query based
ACQUIRE	Flat/Data centric	Limited	Limited	✓	☒	☒	Low	Low	✓	Complex query

- *Hierarchical Routing*

Cluster based routing procedures are also known as Hierarchical routing. It was initially introduced in wired networks. They were very advantageous with respect to scalability, flexibility and efficiency. Furthermore, hierarchical routing is also used in energy-efficient routing. In a hierarchical routing scheme, the data is sensed and accumulated by nodes with lower energy. The collected data is processed and sent by nodes with higher energy.

- *Location based Routing*

In Location based routing, the sensor nodes are dealt with respect to their locations. Using the strengths of incoming signal, the distance between neighboring nodes can be easily calculated. By exchange of this data among neighbors, the relative coordinates of neighboring nodes are estimated. On the other hand, the location of nodes can be effortlessly extracted using communication between satellite and GPS modules in the nodes. Table 5 present the comparison of numerous hierarchical based routing schemes and location based routing schemes.

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Table 5: Hierarchical based routing schemes and location based routing schemes

Routing scheme	Category	Scalability	Mobility	Data aggregation	Multi-path	QoS	Power Consumption	Query	overhead	Localization
LEACH[68]	Hierarchal	Yes (Good)	Fixed BS	Yes	No	No	Max	No	Yes	Yes
TEEN & APTEEN[69]	Hierarchical	Yes (Good)	Fixed BS	Yes	No	No	Max	No	No	Yes
PEGASIS[70]	Hierarchical	Yes (Good)	Fixed BS	No	No	No	Max	No	No	Yes
MECN & SMECN[71]	Hierarchical	Yes (Low)	No	No	No	No	Max	No	Yes	No
OP[72]	Hierarchical	Yes(Low)	No	No	No	No	N/A	No	No	No
HPAR[73]	Hierarchical	Yes (Good)	No	No	No	No	N/A	No	Yes	No
VGA[74]	Hierarchical	Yes (Good)	No	Yes	Yes	No	N/A	No	Yes	Yes
LAXY [75]	location	Yes(Good)	No	No	Yes	Limited	N/A	No	Yes	No
PPRP [76]	Position and location aware	Yes(limited)	No	Yes	No	No	Limited	No	Yes	No

b) Use of Wsn Systems in Underground Coal-Mining Systems

Wireless sensor networks provide efficient communication in various diverse scenarios and widely adopted for various applications. WSN is also adopted for underground coal-mining systems. In this section we discuss about application of WSN for underground communication system. Bhattacharjee et al. [77] described about WSN and presented their use for fire-detection, monitoring and prevention in underground coal-mining systems. According to this process, oxidation, coal temperature increment, oxygen absorption etc. are also monitored for early detection of fire. Qin et al. [78] used Interferometric synthetic aperture radar (InSAR) technique for underground coal mining monitoring system with the help of C-band and L-band wavelength projection. In [79] authors presented fire monitoring for coal-mining using WSN. In this work, a multi-agent model is developed where belief, desire and Intention components are considered. As discussed in previous section, WSN routing and security is also a challenging task, similarly, for underground monitoring is also face these issues. To deal with this, Shuo et al [80] presented a multi-path routing for secure data communication. In this process, residual energy and link quality parameters are considered for next hop and routing path.

Generally, underground monitoring systems use wired transmission which gets damaged during accidents and longtime deployment. This may lead to inaccurate data collection. To overcome this, wireless sensor networks play important role. However, localization of nodes in tunnels is a challenging task which can cause several issues such as energy consumption, weak connectivity, long delays, and a short lifetime. To overcome this, xia et al. [81] presented transmission power control algorithm which identifies optimal radius for communication and optimize cluster head selection process. Minhas, et al. [82] presented a combined scheme of WSN localization and event monitoring systems. In order to develop miner localization and activity monitoring low-power 3-axis MEMS accelerometer is used. Zhao et al [83] described WSN based methodology for WSN monitoring by collecting various information such as Dust Density, Temperature, Wind Speed, Gas Density and Carbonic Oxide Density. This data is transmitted to sink node for further processing.

Zhang et al. [84] discussed about coal mine monitoring system where existing Cable Monitoring System (CMS) is also discussed. For further improving the monitoring periodic inspection and interrupt service are discussed which helps for data collection, forwarding and reception. For underground applications, cost and energy effective solution is highly demanded which can collect data efficiently and can be used for monitoring. For real-time applications, hardware modules are required for WSN monitoring for underground mines. To achieve this, in [84], authors have adapted ZigBee model due to its significant nature for this type of diverse environments. Kumar et al. [85] discussed about growth of mining industries and presented that enhanced mine productivity and worker safety can enhance the growth of mining industry. Productivity can be enhanced by varying some set of parameters and reducing the human error.

Recently, Ramesh et al. [86] presented a study for landslide monitoring using wireless sensor network. This networking system has been deployed 3 years back and has collected huge amount of data such as rainfall measure, moisture, pressure, soil properties etc. which can help to understand the situation for land slide monitoring. Sicignano et al. [88] focused on the underground WSN multimedia communication and developed a new approach for voice communication. This work is based on the multi-hop communicating protocol. This protocol helps to manage delay sensitive messages and provides better QoS. Zhou [89] discussed about wireless sensor network deployment and localization in underground coal mining First of all, a 3D type-band model is developed for node deployment where various parameters such as radio features, sensing efficiency, redundancy principles and coverage features. Li [90] et al. developed Structure-Aware Self-Adaptive WSN. This model is capable to detect activity variation which provides operating stability to the WSN. However huge amount of work has been carried out in this field of underground coal-mine monitoring with the help of wireless sensor networks but still secure and significant model need to be developed which can provide better communication quality with lesser resource utilization [91].

IV. Conclusion

Due to increasing demand of wireless communication, wireless sensor networks have gained huge attraction from researchers and industrial aspects. In this article, we have presented a comprehensive survey of wireless communication and monitoring system. Generally, performance of wireless sensor network depends on the following aspects: network localization, network routing and network lifetime. Several studies have been presented based on this assumption which focuses on network performance improvement. Comprehensive survey presented recent techniques of localization routing and network lifetime enhancement. however, due to network congestion issues still there is a need to improve the conventional approaches. Based on the working of wireless sensor networks, we would focus on the coal-mining monitoring model for real-time applications. In order to monitor the coal-mine monitoring, a WSN based scheme will be developed which contains aforementioned stages i.e. routing, localization and energy efficient communication. Conventional routing protocols face various challenges as discussed in this article. Based on these studies, a motivation of routing protocol development is presented. Furthermore, routing protocol classification is also presented along with the advantages and drawbacks which can help to select the efficient routing protocol. Along with this, localization classification i.e. ranges based and range free approach is also discussed with comparative analysis. Hence this compete survey is focused on the performance improvement of WSN which can be utilized for coal-mine monitoring.

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