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Tolerance Based Adaptable Framework for Proficient Massive Data Mining in Wireless Sensor Networks

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Abstract: Wireless Sensor Network (WSN) is more popular because of its wide application in real-time. Sensor network provides immensely valuable information from the environment where it is implemented. Consequently, effective data mining is required in sensor networks. Processing huge data set is difficult in WSN due to limited power, memory space and short-range communication. Various data mining algorithms for WSN has been proposed but all existing algorithms fails to handle massive data set. To process huge data set effectively researchers constructed a framework in this study. Moreover, structure forms a cluster in a highly coverage area of WSN among the nodes. Cluster formation is carried through neural networks. It uses Bayesian data sharing technique to monitor the activity of database and data sharing. Along with communication problems, mobility of nodes causes break in communication and also leads to fault occurrence. In order to face the mobility issues, researchers proposed a fault tolerance method through creating an optimal sensor network. The experimental result demonstrates the framework is efficient in handling huge data set.

Key words: Data mining, wireless sensor network, fault tolerance, neural network, bayesian data sharing, k-nearest neighbor

INTRODUCTION

Wireless Sensor Network (WSN) is a recent technology which acts as a bridge to the physical world. WSNs are deployed to gather physical information from an environment where it is implemented. It captures the attention of many researchers encircling an extensive range of ideas from military applications to environmental protection. WSN is deployed in environmentally inaccessible areas where energy efficiency is a paramount importance and also communication is more expensive than data processing operation. Though sensor networks are promising technology, it has some issues such as:

- Limited battery power, memory and CPU resources
- Short range wireless networking
- Influences of environment on SN and sensing quality

Apart from these issues, it is still broadly implemented in various fields. Its rising use of sensing from medical to military application inquires for the development of the data mining system that is specific to sensor networks.

WSN produces large volume of raw data that are correlated over time. It will produce many missing or illogical values for some of the parameters measured by the sensor. This problem of generating useless information is due to the transmission failure since WSN has a short range of networking and a faulty reading by SN because of the hindrance of sensor devices or low battery levels. Mining missing values is not easy and on removing such missing and noisy data from the database will also remove legitimate values. Data obtained from SN has a high-level of redundancy both in space and time. To mine such collected data is a tough job. Using data compression technique such as Principal Component Analysis (PCA) or Independent Component Analysis (ICA), researchers can reduce such complexities in data gathered from SN. This may affect the time and memory capacity of all SN.

Standard Data Mining (DM) system is not applicable to WSN because its assumption about characteristics of data sources, reliability and availability no longer hold in sensor networks. Therefore, the classical database system has to be modified significantly to adapt WSN. Data mining over especially distributed DB which is under the constraints of storage, energy and storage are daunting.

Easiest way for analyzing the data of the Sensor Node (SN) is to have a Centralized Server (CS). CS maintains the data collected from various SN in a database. Centralized data management is not scalable due to that the given data cannot be transmitted to and

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stored at a CS without adversely impacting lifetime of network since very limited energy resources are available at each node. In addition to the limited battery life, WSN also depends on memory and processing constraints. These constrain limits the data to be stored locally at SN.

Mobility nature SN affects the presence of node during communication entirely. It causes the communication to end up in between transmission of data from the node to server. Hence, availability and reliability of SN should be considered during the construction of the data processing system. This is due to the reason that data from sensor node to the server are vice versa is transmitted over wireless connections with varying channel characteristics. A data mining system for WSNs must be able to handle variable delay and diverse delivery rate from different nodes.

In order to process data in WSN and to overcome all the problems above-mentioned in this study, researchers proposed a framework. Researchers mainly focus on the communication problems and fault tolerance in WSN. If the problem in communication and tolerance over faults generated by SN is tackled then researchers can obtain a large data processing system for WSN. The architecture of the proposed system is as shown in Fig. 1.

Initially, researchers frame a sensor network with 'n' number of nodes such as: WSN = $\{SN_1, SN_2, SN_3, \ldots SN_{12}\}$. In the architecture at Fig. 1, researchers framed the network with twelve nodes WSN = $\{SN_1, SN_2, SN_3, \ldots SN_{12}\}$. They are deployed at a position 'x' geographically in an environment 'X'. Researchers choose a cluster 'C' which is a subset of sensor network, researchers framed. The characteristic of the cluster is that it has a subset of nodes among the entire set of nodes in WSN with comparably high bandwidth for communication and transferring data is also easier than other nodes. This high coverage area is framed using neural network. In Fig. 1, researchers clustered around six nodes that are the subset of WSN are used to frame C in such a way that C = $\{SN_1, SN_2, SN_3, SN_4, SN_5, SN_6\}$ with efficient data transferring.

The geographical position of the nodes in C is closer to each other than other nodes in the entire network. A Network Access Point (NAP) is constructed to have communication between the C and database. NAP has the responsibility for transferring data between the database and the nodes of C and monitoring the location of nodes continuously. It receives the file from a database for processing then calculates the size of the file and equally shares the file among the nodes in the C. For example, a file size with 60 MB of data is needed to be processed then the NAP divides the file equally among the nodes in OSN such as 10 MB for all $\{SN_1, SN_2, SN_3, SN_4, SN_5, SN_6\}$ nodes. This way of processing will reduce the time and also the memory requirement of sensor nodes. This helps the sensor nodes having less battery power to save energy of each node.

As explained before, mobility nature or less battery power of the node may cause a node in C to move away from the coverage area of the framed cluster. In such cases sharing of a file is affected by the number of nodes as the mobility cause the total number of nodes in C to be decreased. This fault can be recovered through the Optimal Network Topology (ONT). Since, ONT formation, k-nearest neighbour algorithm is used to find the nearest node, i.e., geographically nearer to C. This node is sensed using Received Signal Strength (RSS_i) of a node from NAP. By ONT large data set can be processed effectively.

In the example if SN_6 is moved away from the coverage area of C then through continuous search by NAP researchers spot and path from $SN_3 \rightarrow SN_7$ is established as shown in Fig. 2. This makes the OSN stable even if nodes move away due to its mobility nature or shut down because of low battery.

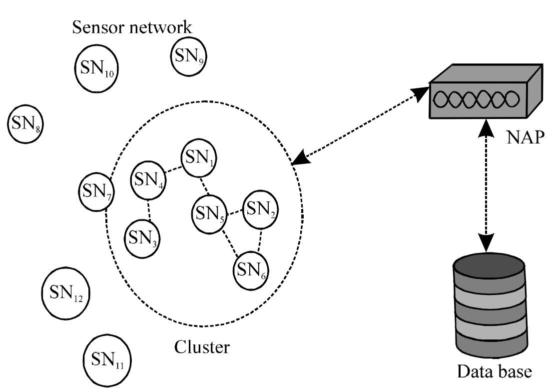

Fig. 1: Architecture of WSN

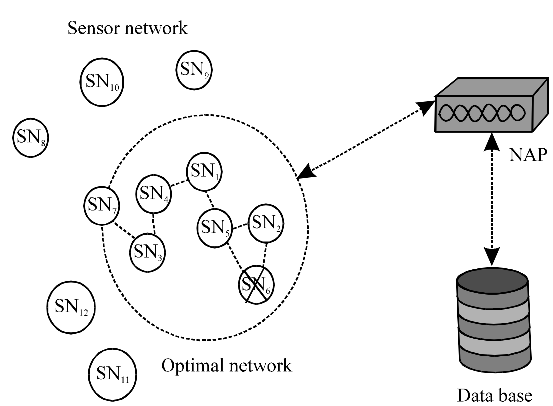

Fig. 2: Optimal network topology

LITERATURE REVIEW

Communication range, mobility, fault tolerance are the major factors that should be considered during data mining. Mobility of the node makes the communication failure and therefore the fault should be recovered efficiently. This study gives an overview of ideas of different authors that helps in efficient data mining. Galluzzi and Herman (2012) summarized the surveys current improvement in the problems of neighbor discovery for wireless sensor networks. The essential ideas behind these protocols are explained which embrace deterministic schedules of randomized schedules, waking and sleeping and combinatorial techniques to make certain discovery. A detailed description of selected data mining algorithms for WSN was presented by the researchers in the study (Stankovic *et al*., 2012). They also provided elaborate solutions of the existing proposed methods with major focus on their classification. Criteria for classification in WSN's data mining were presented through four basic groups and 16 classes. They have also mentioned the research challenges that were still to be solved. As the sensor nodes are low powered and unreliable the DM process may affect the lifetime of the sensor nodes. An efficient load scheduling technique can carry the DM without affecting the lifetime of the sensor nodes.

Data mining process in WSN would require enormous energy and highly coverage area. These requirements have been fulfilled by framing clusters. In general, clusters were the collection of similar types. These cluster formations would enhance the DM process by consuming less energy. Energy efficient cluster formations were projected in the study by Cheng *et al*. (2011) and Wei *et al*. (2011). The decentralized clustering algorithm was anticipated by Cheng *et al*. (2011) based on the social insect colony structure for WSN. Simulation results showed that this algorithm improves the lifetime of the network and coverage. A distributed energy efficient clustering algorithm was projected by Wei *et al*. (2011) with the aim to save the node lifetime in the hot spots of WSN. This algorithm found the cluster size based on the hop distance. Performance analysis showed that the distributed energy efficient algorithm was more effective than HEED and UCR, well-known clustering algorithms. A new dimension of clustering technique was found by Youssef *et al*. (2009) and Guo *et al*. (2009). They have generated overlapping multi-hop clusters. These cluster formations would help in node localization and time synchronization. A distributed multi-hop clustering algorithm (KOCA) was proposed by Youssef *et al*. (2009) that would help solve the overlapping clustering problem.

Sensor network that has no prior knowledge about the deployment and the network environment can use Random Connection Model (Guo *et al*., 2009) to cluster nodes in these situations.

Mobility based clustering algorithm was contemplated by Deng *et al*. (2011). Here, a sensor node was elected by itself as a cluster head based on the energy and mobility. All non-cluster-head nodes connected with CH during clustering depended on the estimated connection time. This research was compared with the CBR and LEACH-mobile protocols and results showed that it outperformed the comparative methods in terms of average energy and control overhead. Also, results showed that it is adaptable to the highly mobile environment. Liao *et al*. (2010) discuss about the grid-based dynamic load balancing approach for data-centric storage in sensor networks that relies on two schemes, first a cover-up scheme to deal with a problem of a storage node whose memory space is exhausted. This scheme can regulate the number of storage nodes dynamically, in second scheme the multi-threshold levels to accomplish load balancing in each grid and all nodes gets load balancing.

Borbash *et al*. (2007) introduced an asynchronous algorithm, named probabilistic neighbour algorithm which stimulates all the nodes in WSN to develop a list of neighbour node that are always incomplete. They derived the parameters which maximizes the count of neighbour node discovery in a fixed time. Following the research by Wei *et al*. (2011) an energy efficient neighbour discovery protocol were proposed by Kohvakka *et al*. (2009) with the aim to reduce the cost of scan required to discover neighbour. Experimental results expressed that the protocol reduces the node's energy consumption up to 80% in 1-3 m sec^{-1} node mobility. A new way to find the neighbour through signal processing was proposed by Angelosante *et al*. (2010). This method was applied in physical layer with an assumption that node transmits copies of their signature in waveform coupled with their identities. This algorithm handled multi-user interface environments. Existing algorithms mostly developed for the protocol layer this is insufficient in terms of energy since those algorithms waste energy through packet collisions. Therefore, Angelosante *et al*. (2010) advised to use the signal processing techniques which are applicable at the physical level. A framework was proposed by Zhang *et al*. (2012) called compressed neighbour discovery that enabled all the nodes in the WSN to detect its neighbours simultaneously. Efficient processing of DM can be carried through paralleling the job. A paradigm was proposed by Serpen and Li (2011) that provided a platform for distributed and parallel computation of the maximum independent set. During processing there were chances for faulty information generation in order to overcome those faulty information scholars proposed a distributed agglomerative cluster based anomaly detection algorithm named DACAD to find readings that are wrong based on kNN approach.

A stairs scheduling method for data collection in a tiered large-scale sensor network were proposed by Chen *et al.* (2013). It's based on three aspects of performance deliberation including multihop communication reliability, network longevity and sensing system cost minimization. A stairs duty-cycle scheduling method for lower-tier sensors designed to make same cluster sleep cooperatively for most of the time and wake up in the assigned sequence of multihop communication. Zhang *et al.* (2010), address the problem of outlier detection in WSNs and afford a technique based taxonomy structure to classify present outlier detection methods designed for wireless sensor networks. In addition, it presents a technique-based taxonomy and a comparative table to be used as an instruction to choose a method appropriate for the application at hand based on characteristics such as outlier type, outlier identity, data type and outlier degree. The adaptive clustering algorithm that improves the reliability when a head node gets any problem without losing data by Midhunkumar and Srinivas (2013). A clustering algorithm was provided to group the sensors of a network into clusters of different sizes. The sizes of the clusters in the network were determined based on an input to the algorithm that contained the initial number of required clusters of each size. A large number of non-sink nodes collects data and send the collected data to these sinks. Significantly cuts down on energy consumption by ensuring that a large number of sensor nodes can go into a deep sleep mode for a main part of their lifetime.

With these ideas in the background, researchers framed the proposed research for efficient data mining in WSN with considerations in energy, lifetime, coverage and fault occurrence.

PROPOSED RESEARCH

Processing large data set in a sensor network is a more challenging task. It is hard to have continuous communication between sensor node even with very less mobility. In this study, researchers frame a framework for efficient data processing of large data set in a WSN. For the processing of massive data set in WSN through the framework researchers deployed the wireless sensor network through deploying 'n' number of SN {SN_1, SN_2,..., Sn_n}. The flow of the proposed framework is expressed in Fig. 3. The data mining process is carried out as network model.

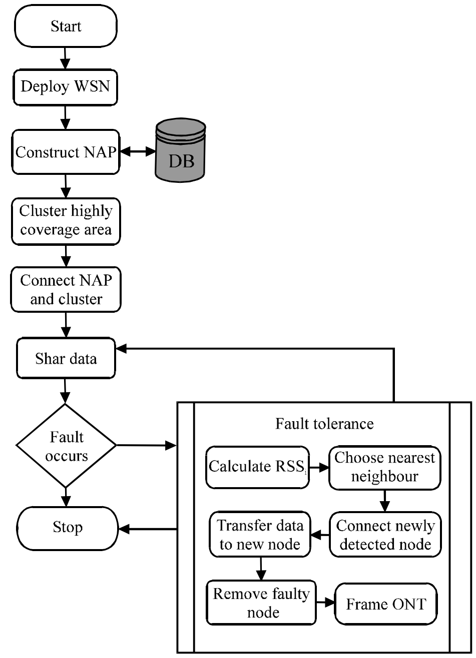

Fig. 3: Overall flow of proposed method

Network model: WSN is deployed with the set of nodes with the assumption that a subset of nodes in sensor network always has the highest coverage and also less mobility. These nodes are identified and classified using an artificial neural network algorithm. This classified networks are clustered together to form a sunset. The neural networks are used for the reason that it will not burden the main memory since it uses very simple calculations whereas other algorithms use complex computations. Its additional advantage is that it requires low communication cost. There are several unsupervised artificial neural network models have been proposed. Among the existing model researchers use Adaptive Resonance Theory (ART). ART run fully automated which does not require any outside control. ART self organizes and adapts itself to the new environment without forgetting the earlier situations in the network. This makes ART as a best choice for applying in the sensor networks having high mobility. This algorithm runs on each node and finds the area with high coverage. The nodes under this detected coverage area are grouped together to form a cluster.

In this study, researchers assumed that all the nodes in the network are always sensed using an access point named NAP. This NAP is solely responsible for communication between the DB and nodes in the network. Its main responsibility is to monitor the nodes in the network. It knows the number of nodes and location of the cluster in the network. To maintain consistency in the number of nodes always senses the nodes that are very close to the cluster. NAP's key role is to take necessary steps in case of fault occurrence. In addition to monitoring all the nodes in the network it senses and connect the cluster that is formed using ART. Always there is a connection between the cluster and NAP. Data sharing between the nodes are carried out by the NAP, it shares the load among the nodes inefficient way.

Data sharing: DB sends the data set to NAP that has to be processed. On receiving the data set NAP calculates the data set size in bytes. The data sets is shared equally among all the nodes in the cluster. For data sharing Bayesian Method is used. NPA using the following formula to calculate the amount of work that to be assigned to each node in the network. In the equation:

$$DS_{size_{SN}} = \frac{DS_{size}}{TNC_{SN}} \quad (1)$$

Where:

DS_{size} = The total size of the data set in terms of bytes given by DB to NAP

TNC_{SN} = The total number of nodes in the cluster that researchers framed

DS_{sizeSN} = The amount of work allotted to a node in the cluster

To implement this equation, it is required to maintain the total number of nodes in the cluster constantly throughout the data mining process. So, NAP always senses the nodes of the cluster by signal strength of each node. This continuity sensing is used to know about the position and status of the nodes in the cluster. If any node shows less strength than a threshold then NAP starts the process of fault tolerance to choose a replacing node in order to transfer the data and process of the node that has less signal strength to the node. If the NAP fails to detect replacing node before the node with low signal strength moves away from the coverage area of the cluster or dead due to low battery then it is impossible to implement the above formula. Therefore, the data mining process interrupted. To avoid this situation, NAP carries the fault tolerance procedure. This fault tolerance procedure is used to maintain the number of nodes in the cluster to make the earlier equation applicable of all time without interrupting the process of data mining.

Fault tolerance: It is mandatory to maintain the number of nodes in the cluster since if there is a change in the number of nodes during the processing of data set then a fault occurs. To overcome this nearest neighbour is chosen and transfers the data to the nearest that it is found.

Choose nearest neighbour: The nearest neighbour is found using k-nearest neighbour algorithm. This algorithm finds the nodes that are nearer to the cluster coverage area without any knowledge about the underlying mechanism. Among the k-nodes detected as closer to the cluster coverage single node is selected as the replacing node. In order to select the replacing node we use Received Signal Strength indication (RSSi). The measure of power presented in a received signal is calculated and named as RSSi. It is a radio receiver technology metric which is invisible to the users of the receiver. It indicates the power level of the node received by the NAP. This explicitly indicates that if the power is higher the strength of the node's signal is stronger. For example, consider the Fig. 1 and 2 which denotes that NAP sensed that node has lower signal strength to replace this node, it finds the node is the geographically nearest node as well as with high RSSi value. Therefore, NAP chooses as the replacing node for. Once the replacing node is determined then NAP transfers the data and process from to.

Transfer control Before the node SN_6 moves out of coverage, NAP will transfer the data and process of node SN_6 to the node SN_7. This is achieved by creating the communication link between the nodes that are nearer to the SN_7 in the cluster and transfer the data to it through the communication path it established. For example, from Fig. 2 it is obvious that communication link is created between the nodes $SN_7$and the node SN_3. SN_3 is the node in the cluster which is nearer SN_7. Similar to link creation the existing links for the node SN_6 is permanently discarded. In Fig. 2, the link between SN_5-SN_6 and SN_2 and SN_6 are discarded. The reformed cluster acts as the optimal network topology and takes the advantage of prevention of fault tolerance, low communication overhead and less communication time.

EXPERIMENTAL RESULTS

As stated, sensor network is composed of a large number of sensor nodes deployed in a specific environment. The deployed sensor nodes sense and report the information about the environment to the base station. Since, the nodes have high energy and power constraints, there are some limitations on managing massive data. In order to overcome those limitations and

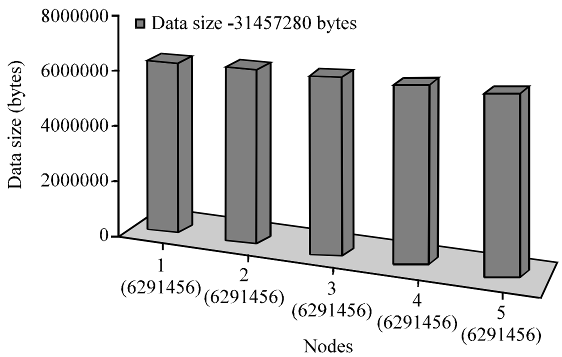

Fig. 4: Data sharing of a single dataset

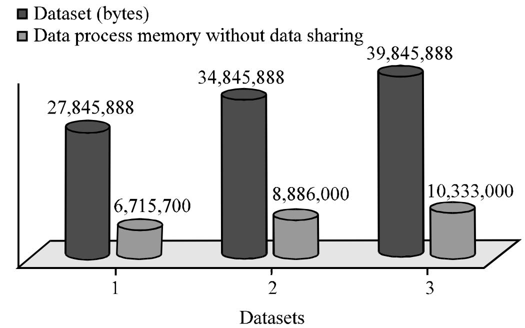

Fig. 5: Process memory consumption before ONT

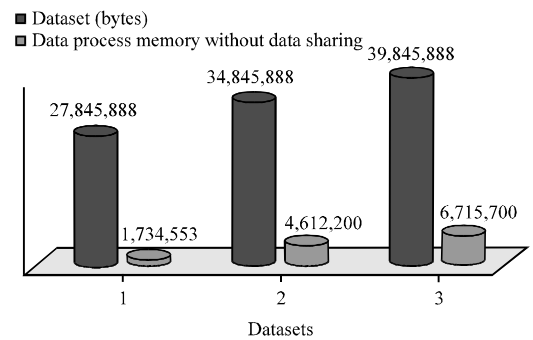

Fig. 6: Process memory consumption after ONT

enhance the possibilities of communication overhead and fault tolerance in WSN an adaptive framework with NAP is developed and evaluated here. For the evaluation, researchers used static datasets, available from http://nhts.ornl.gov/download.shtml; http://humangenome.duke.edu/available-datasets. According to the proposed methodology, the cluster is formed by the nodes having high coverage area. After locating and clustering the sensor nodes having a high coverage area, it will be linked to NAP for further communication. Consecutively, the massive data to be shared and processed is loaded on the NAP which is responsible for efficient data sharing among the clusters to carry out the required process. The massive data obtained by the NAP from the database is dispersed among the nodes in the cluster for further processing using Eq. 1.

Before the data distribution, the capacity of the total cluster and the individual nodes in the cluster have to be examined. Following that the data sharing process takes place in an equal distribution manner. Figure 4 shows the equal sharing of data among the cluster nodes with the assumption that there are five sensor nodes are under the high coverage area and formed a cluster. The data size of the assumed dataset is given as 31457280 bytes and that is distributed to the 5 nodes equally 6291456 each for adept processing.

It is substantial in the approach that the number of nodes in the cluster has to be maintained constant for successful processing over the dataset since the sensor nodes having high mobility.

In that case, there arises a problem that any of the nodes in the cluster may lose its power or fail to communicate with the others. For resolving that problem and provide an effective communication over the network the remaining nodes that are presented out of the cluster has to be monitored and the nearest neighbor for each node in the cluster has to be chosen. For finding the

Table 1: Dataset information

Dataset	Size (bytes)
1	27845888
2	34845888
3	39845888

nearest neighbor node, k-nearest neighbor algorithm is used here. By analyzing RSS_i, the neighbor nodes with similar capacity for each node are determined and the weak node is replaced with that neighbor node. This paves way for maintaining the nodes in the cluster as constant and the ART is employed for self organization and adaption on new environment without forgetting the earlier situations in the network. That newly formed network is termed as ONT. For substantiation, process memory consumption is made before forming ONT and after the ONT formation. The examination is done with three data sets with variable sizes (Table 1).

Figure 5 and 6 show the process memory consumption before and after ONT formation. Datasets with different sizes are analyzed here. Before the ONT formation, i.e., generic data sharing is made with random distribution of data over the network without any consideration of coverage area. Therefore, the process needs significantly higher memory for processing the data. On the other side, the proposed methodology forms an ONT with nodes having high coverage area. The data

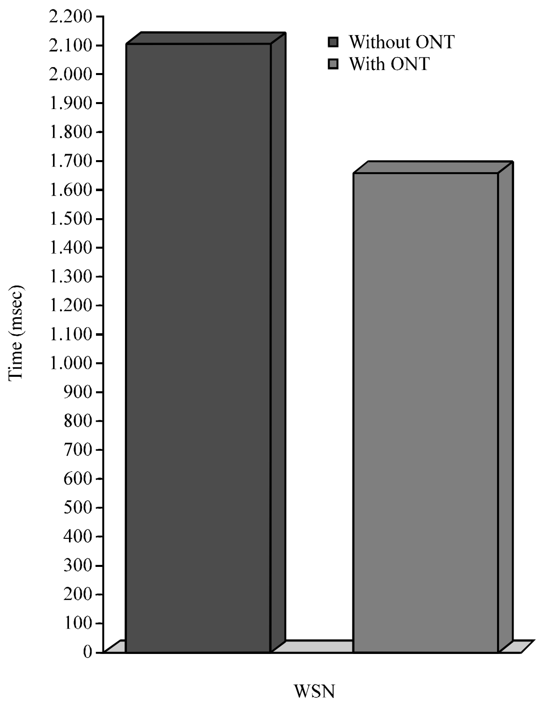

Fig. 7: Processing time for existing and proposed

consumption is done by NAP depending on that ONT. Hence, the memory needed for data processing is moderately condensed by the affirmed research.

Figure 7 presented above shows the time analysis for processing different data sets with variable size. With the random distribution of data over the deployed sensor nodes in WSN, needs increasing time for processing whereas the processing time will be reduced by the adduced work with the ONT formation of the nodes having high coverage area. The immense part of the work is analyzing the strength of each node using RSS_i. When it is noted that any node loses the energy, it will be replaced with some other node which is having closest coverage area and strength wherein the replacing node is determined by the effective KNN Method. Thus, the reformed cluster involves in preventing the fault occurrence and low communication overhead and the process tremendously reduces the memory and time consumption for processing the massive data. It reveals that the proposed method consumes less time than the existing method. This explicitly denotes that proposed method is faster than the existing method.

CONCLUSION

The data mining in WSN highly depends on the factors such as memory space, short-range communication, limited power, etc. There are very few successful methods proposed earlier for efficient data mining to handle massive data set. The proposed research in this study acts effectively to process huge data set in WSN. Researchers find a high coverage area in the WSN and form a cluster among the nodes that fall within that area using neural network. NAP is constructed to communicate between the database and nodes in WSN and it is also responsible for sharing data among the nodes in the network. The proposed method uses RSSi to find the strength of the nodes in the cluster. If any node tends to fail during processing of data mining is found by the NAP using node's RSSi and that node is replaced by another nearest node that is not in the cluster. Nearest neighbor is found using the k-nearest neighbor algorithm. Optimal Network Topology is formed if there is a tendency for node failure to make the number of nodes in the network stable throughout the data mining process. Experimental results show that our proposed method effectively processes the huge data with reduced time and memory utilization. In the future, researchers plan to extend the work of tracking the sensor node's status in terms of bandwidth and providing inter-cluster communication that enhances the effective processing over large data sets.

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