ADAPTIVE TECHNIQUES FOR LOAD DISTRIBUTION IN WIRELESS SENSORS NETWORK

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ABSTRACT— *Wireless sensors network (WSN) is gaining much attention recently. It has been very widely adopted within home automation, offices, roads, and smart city. Thus, sensors come together to form an IoT scenario where things can interact with each other for different purposes. Consequently, the smart city trend is going very fast which is backed up with a fully interconnected environment such as buildings, traffic lights, ATM machines, and EHealth. However, these tiny spread sensors are equipped with a small battery, computing resources, and efficiency. Hence, any over-utilization of these resources shall lead to acting node depletion which would subsequently lead to network collapse. Hence, this paper proposes a new algorithm to balance the load over wireless sensors and increase network efficiency simultaneously. Intensive simulation results have shown that the proposed algorithm is effective in terms of efficiency, load distribution, Betweenness, Closeness, and Degree.*

Keywords—, WSN, load distribution, Betweenness, degree, closeness.

I. INTRODUCTION

Wireless sensors network (WSN) plays a vital role in date collection such as weather conditions, traffic lights incidents, and dynamic automation of homes and hospitals [1]. Moreover, It has been used much in health checks such as gauging conditions of patients and follow up their health regularly. Nowadays, WSN is adopted in the transformation of cities into a smart city, and this move could be considered as one of the most powerful adoptions in WSN. Consequently, big data is more generated which needs careful consideration in terms of data classification and analysis [2].

Data collection and transmission are part of the core business of WSN where devices communicate with each other to compile data and requests [3]. However, as sensors offer their resources and life span at expenses of contribution to the network, this causes an issue for their survival on the network since energy can be consumed at any time due to the overload of work [4]. Therefore, various techniques were proposed in the literature to address the issues related to power consumption and the life span of WSN such as [5-7}. On the other hand, WSN has faced some issues and limitations on load distribution among nodes in the network [8]. Not only that but also the handover between nodes is done with no consideration of nodes conditions such as load and energy efficiency. These are considered among other major challenges in WSN where nodes could lose data and affect all the processed data and compiled easily due to a node overload and power consumption. Therefore, load distribution is one of the vivid topics in WSN , and It has been discussed and investigated by many recent studies which will be thoroughly discussed in the related work section.

This paper looks at the load distribution issues in WSN. Henceforth, new techniques have been proposed to alleviate these limitations and enhance overall network efficiency. Thus, the proposed algorithm combines network centrality and computer networks together in order to get the most use of it. Such combination helps in managing sensor nodes and distribute the load evenly. Simulation results have shown better performance in comparing the proposed algorithm against normal benchmarking in terms of efficiency and load distribution.

II. RELATED WORK

Load distribution is one of the major challenges in wireless sensors networks (WSN). It does not only affect the sensor nodes but also affects base station which is the nodes with high power and resources. Research has concentrated on reviewing various issues in WSN from different angles. A multi-hop protocol has been proposed by [9] where multi-hops sinks have been adapted to evaluate the load distribution in WSN. Additionally, authors in [10] have proposed a technique in distributing the load uniformly among the cluster head and members based upon the associative clustering model. On the other hand, load distribution is also discussed by [11] where authors proposed to rely on distance and density on distributing the load among WSN.

Furthermore, authors in [12] have proposed a technique that generates minimum traffic based upon graded node deployment strategy. In their technique, the traffic generated is only for small coverage where packets are delivered via multi-hop through the shortest path possible. In line with this work, another study was done by [13] where they have focused on underwater wireless sensor network, load-based time allocation has been proposed where nodes are selected to instantaneous schemes for the network load, so based upon the nodes priority and a number of back-off changes, nodes are selected accordingly. Hence, as a result of this proposed technique, the load is well distributed and throughput is increased accordingly.

Load balancing is also looked at by [14] where they have acquired the features of multi-path in wireless sensors network. In their proposal, and in order to achieve a load balancing, packets are segmented into small packets and transmitted via multi-path. This is backed up by a congestion control and load balancing algorithm which adjusts the load over multipath. On the other hand, traffic distribution in linear wireless was also analyzed by [15] where they proofed that the closer the node to the sink, the least traffic is carried out. On the other side, when nodes are away of the sink, this causes an issue of reliability due to traffic relay on the whole network. Furthermore, authors in [16] have shown an adaptive technique of a superflow where traffic is converged according to a specific vector which subsequently leads to balancing the traffic load over sensors. Their work was focused on the aspect of routing and information forwarding of the remaining traffic in the network.

Clustering is also one of the proposed solutions to balance the load in the mobile storage network, this was introduced by [17] were variations of k-means was the key to cluster the nodes with nearly at the same size. Moreover, clustering was also proposed by [18] where clustering of nodes was combined with traffic distribution using traffic splitting protocol (TSP). the proposed scenario by [18] was also effective on enhancing the power consumption as well. Furthermore, authors in [19] have studies various WSN protocols for load balancing such as distributed load-balancing routing (DLBR), E-leach algorithm, and k-path splitting. Each algorithm has its own advantages and disadvantages in terms of load balancing.

In addition to the above-mentioned studies, clustering is gaining much attention by other researchers as in [20]. In this study, authors have combined clustering and multipath secured relay. Hence, the aim of such a combination is to balance the load and at the same time guarantee that no malicious could occur in case of transmission. Their results have shown a clear enhancement in terms of quality of service (QoS), consumption, and throughput. On the other hand, 2D mesh WSN has also been discussed by [21] where a base station (BS) has been placed in 4 corners of the 2D mesh network. The aim of this technique was to reduce the load in the central nodes and prolong the span of WSN. On the other hand, the concept pf supernodes are also considered to balance the load in WSN. This is proposed by [22] where supernodes is elected based upon their power and efficient communication. The objective of this strategy was to transfer the traffic into those nodes close to the sink with less traffic.

In continuation of previous studies, this paper looks at the load distribution challenge in WSN. However, the technique adapted is different than the previously proposed solutions by existing studies. Therefore, the proposed algorithm combines two different techniques together which are network centrality and computer networks. The aim of such a combination is to get the advantage of defining the centrality of the nodes, and then distribute the load by consideration of nodes closeness of each other by redirecting the links from those nodes with high connectivity to other nearby nodes.

III. PROPOSED ALGORITHM

In this section the proposed algorithm is detailed. Since load distribution plays a critical role in the sustainability of WSN due to the ill effect which could lead to a network failure since nodes can be overloaded and battery depletion occurs and leads to network collapse. Hence, the proposed algorithm introduces and combines different techniques:

A. Network centrality

This is one of the components that has been introduced in the proposed algorithm which measures the conditions and efficiency of WSN. It reflects the interconnectivity among nodes in the network such as an actuator, sensors, objects and so on. Moreover, the degree level of correspondence between nodes which gives insightful results of the best positioning of nodes within WSN. In the proposed algorithm, the centrality metric has been adapted as defined in [23].

B. Load distribution

In this part of the proposed algorithm, load distribution among nodes in the network is measured through communicability [24]. This metrics is adapted from network science which gives the condition of each and every single node in the network with an exact value and budget. Hence, these values reflect how the nodes are interconnected with each other across the WSN. Henceforth, the algorithm compiles all these values dynamically and ranks them as a top-down approach. The aim of this ranking will be part of the next parameter.

C. handover

Handover refers to the action taken by the algorithm in case of redistributing the load among nodes. Basically, this part of the algorithm is dependently linked with the previous parameters as stated in A&B. Therefore, the main role of this function is to check the load distribution per the generated output values by centrality metric and load distribution. The purpose of this technique is to distribute the load among nodes by handing over the connections from the overloaded nodes into those nodes with the least connections. This action is carried out periodically according to the updated output values by A&B.

IV. RESULTS AND DISCUSSION

In order to evaluate the proposed algorithm, Python has been selected as a platform for simulation [26]. The advantage of such a platform shows on the multi embedded libraries which give the flexibility of calling different metrics from different science. Moreover, there are different topologies to simulate WSN. However, The Erdős–Rényi model [1] was used to generate the graphs. It gives multi-option to simulate many types of WSN at the various size of the network. Furthermore, simulation has been run over the different sizes of the network in order to adjudicate the robustness of the proposed techniques over different scale of WSN.

In order to gauge the performance properly, two scenarios have been introduced. The first approach represents the proposed algorithm whereas the second approach was introduced to mimic a default normal scenario with no techniques and run as widespread sensors (referred to as "off-loading distribution"). As part of the evaluation of the proposed algorithm, different parameters have been selected carefully to show the performance and counterpart such metrics with a benchmarking of default WSN topologies. These metrics are defined as follow:

Load Distribution: The aim of this metric is to show the output of both implemented algorithms as a result of the injected techniques. Load distribution has an ill effect positively not only on traffic but also on energy and congestion control from sensors to the sink and base station (BS). Figure 1 gives a clear indication of load distribution. It can be seen in the shown plot, the proposed algorithm is capable to maintain full load distribution against the off-loading distribution scenario. The justification behind such consistent results of the proposed algorithm is the handover technique that acts on distributing the interconnections among nodes across a wireless sensors network. This periodical

[1] "Erdos Renyi models.pdf." https://en.wikipedia.org/wiki/Erdős–Rényi_model

handover continues until a certain point where the interconnection among sensors are fully distributed and the existing condition is linked with the communicability values which are measured continuously. On the other hand, the other scenario shows high consistent results across network size which will affect the other metrics that will be shown in the rest of this section.

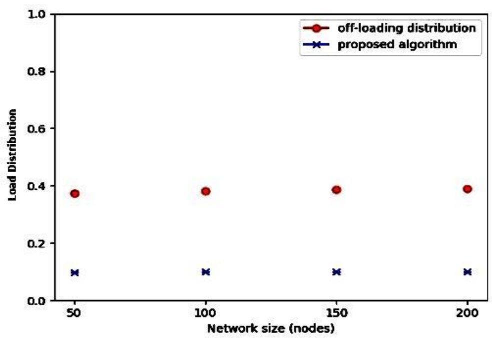

Figure 1 Load distribution

However, It is very important to highlight that both algorithms have been run at the same conditions in terms of network size and graph. Moreover, figure 1 gives another proof that the proposed algorithm is showing consistent results at various levels of network size. This is clear evidence of the reliability of the proposed techniques in distributing the load irrespective of the network size. On the other hand, for validation purposes, both algorithms have been run many times to show meaningful results which is shown here as the average and standard deviation of these runs.

Gained Efficiency: This parameter shows the ill effect of the proposed techniques for load distribution. In other words, the better the load distribution, the more efficiency is gained across the network. In the proposed algorithm, gained efficiency (GE) is defined as follows:

GE = (Δ/max values) * 100

Where Δ is (MAX - the overall communicability value). The Max value, in this case, is 1 (depending on the metrics scale).

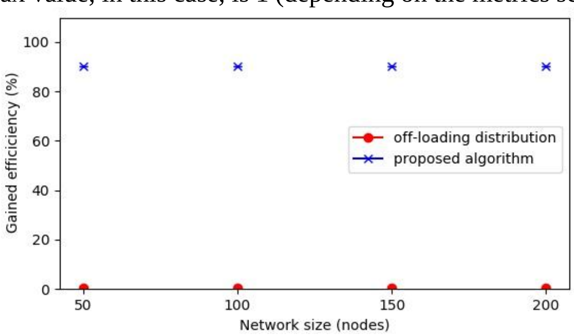

Figure 2 Gained efficiency

Figure 2 depicts the gained efficiency across WSN which shows the performance of the proposed algorithm against the off-loading distribution. It is very evident that the proposed techniques for distributing the load are effectively enhancing the efficiency and reliability across the nodes. Such results will impact on transmission, end-to-end delay, energy consumption, traffic forward among nodes. On the other hand, the other scenario is achieving almost obsolete efficiency due to the number of connections that are handled by most of the sensors in the network and neglecting the rest of the nodes. Such behavior affects the energy and the overall efficiency of the network which would lead to nodes failure accordingly.

However, by looking carefully to figure 1, It can be claimed that this result in figure 2 is aligned with better load distribution. Furthermore, results give another line of confirmation that distributing the load in the network reflects positively on the sustainability and reliability of WSN. Moreover, a further observation about figure 2 is that the performance of the proposed algorithm is not affected by the network size which gives evidence that that the proposed techniques are efficient to deal with any type of dense network.

Degree: This parameter shows the connectivity of each sensor node in the network. It mainly gives an image of the condition of nodes in terms of traffic load distribution and transmission. Such results of this indicator is another judgment of the proposed algorithm in balancing the load among sensors.

Closeness: This factor plays a vital role in the handover technique which is one of the main components of the proposed algorithm. As handover takes place periodically, It is very essential to consider the closeness between sensor nodes. Therefore, this parameter has been selected as one of the measurements of the proposed algorithm to ensure that handover is not done randomly with no consideration of the range of nearby sensors.

Computational time: This parameter is essential in terms of the consumed time of running both algorithms. Thus, It shows the computational efficiency for each algorithm at various levels of network size. Therefore, in the case of complicated scenarios, running time will be one of the critical performance evaluation. So, a large-scale network size has a considerable impact on the performance of implementing dense scenarios.

Number of Iterations: Since the proposed algorithm is based upon set of components such as handover, this means that the algorithm shall run many iterations to achieve the best results. Hence, this parameter is specified to measure the number of iterations. Moreover, this metric is essential in terms of showing the robustness of the proposed algorithm as It will be dealing with various network sizes.

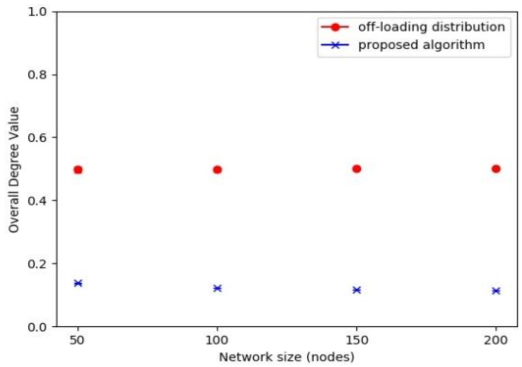

Figure 3 Overall Degree Value

In figure 3, results show that the embedded techniques have shown a slight decrease in degree level, this result confirms the previous output which was emphasized in figure 1 and figure 2. Moreover, the behavior of the proposed algorithm shows that the load distribution techniques have a positive impact, not only at network efficiency but also at degree level at each node across various network sizes. On another hand, by looking closely at the off-loading scenario, It shows a high steady line in high degree level which gives another confirmation that the traffic load and amount of connection among nodes are not considered at all.

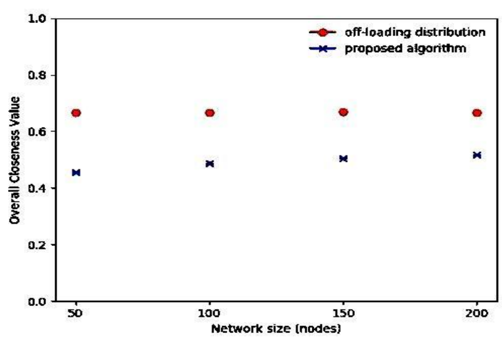

Figure 4 Overall Closeness

Additionally, another indicator of the performance of the proposed algorithm is to be examined through closeness. This metric gives an insightful image of the closeness among sensor nodes. The importance of this parameter comes out from the fact that one of the components of the proposed algorithm is handover. Thus, at each handover process of connections from nodes to others, It is very indispensable to make sure that the handover to be done within the range of sensor nodes. Such behavior assures that no extra signaling and data loss occur due to traffic overload and network congestion. Henceforth, figure 4 shows that the overall closeness is almost consistent against the network size, whereas the other off-loaded scenario is going high across various network size due to the fact that the load is static and not distributed among nodes across the network.

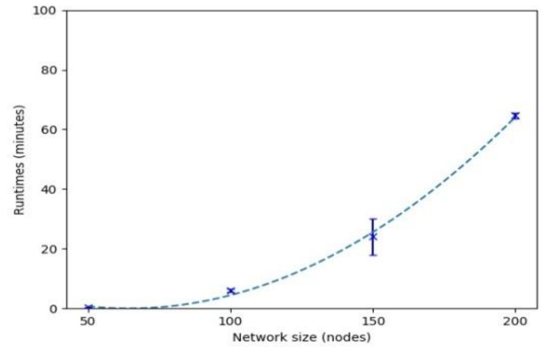

Figure 5 Computational Time

Computational time is another serious issue of the proposed algorithm since it shows the strength of the proposed method. Therefore, dealing with different network sizes has a momentous influence on the performance of implementing such complicated algorithms. This parameter is valuable in showing the computational efficiency of the proposed algorithm, in terms of running time and execution.

Figure 5 shows that the running time increases polynomial against the network size. A careful examination of the amount of elapsed time necessary to run, execute, and achieve the best results over many runs, demonstrates that the algorithm performs very well despite the network size and the complexity of connections among the nodes.

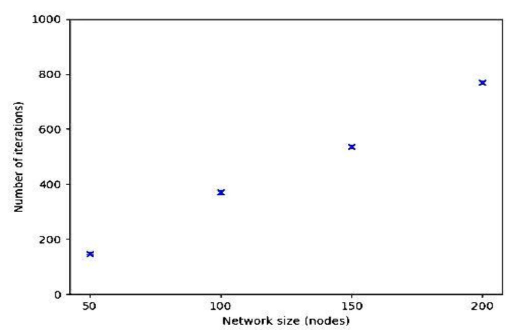

Figure 6 Number of Iterations

Figure 6 depicts that the number of iterations is increasing sharply against the network size. Such behavior implies that the proposed algorithm needs many iterations at each network size to achieve the best optimum results in terms of the main purpose which is the load distribution. This will impact positively on efficiency and other previously discussed metrics.

V. CONCLUSION

Wireless sensors network is one of the main vivid topics that research is given much attention recently. This is due to the fact that WSN has become part of the revolution in technology not only IT era but also in all business models such as health, education, farming, weather, and smart city.

However, as of any technology, WSN faces some challenges and limitations due to its nature such as power failure, life span, load distribution, and so on. Hence, this paper has looked at one of these issues which is the load distribution which affects the network efficiency and the overall QoS. Hence, an algorithm has been proposed which combines different techniques related to network science and computer networks. The performed simulation of the proposed algorithm has shown a clear enhancement in various metrics such as load distribution, efficiency, degree level, closeness, run time, and iterations. As an extension of this work, future work shall focus more on examining the proposed algorithm in terms of the QoS parameters such as end-to-end delay, packet loss, and throughput.

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