International Journal of Scientific Research in Computer Science, Engineering and Information Technology
ISSN : 2456-3307 (www.ijsrcseit.com)
doi : https://doi.org/10.32628/CSEIT217245

An Energy-Efficient Routing Protocol Based on Energy Band and Virtual Localization

Rakesh Ranjan, Amit Kumar
Department of Computer Science and Engineering, MACET Patna

Article Info
Volume 7, Issue 2
Page Number: 184-191
Publication Issue :
March-April-2021
Article History
Accepted : 01 April 2021
Published : 08 April 2021

ABSTRACT

Wireless Sensor Networks (WSN) are Important in various fields which includes military, environmental ,industries, healthcare, biological, home and other commercial applications. Our focus in this dissertation is to prolong the network lifetime of WSNs by reducing and balancing energy consumption during routing process by designing energy efficient clustering protocol for the wireless sensor networks based on energy band based virtual coordinates. The system should be designed in such a way that each node while transmission consumes least amount of energy. This will help in increasing the lifetime of the WSN.

Keywords : Wireless sensor network, Monitoring, Nodes, Sensor

I. INTRODUCTION

The continuous enhancement in communication, computation and hardware technologies enable the new device known as sensor node [1]. The sensor node has capability of communication, computation, and sensing the physical world. Size of sensor nodes varies from some cm*cm to mm*mm. The main important point about the sensor nodes are that they are resource constraints in nature in terms of computation & communication as compared with other computing & communicating devices [2][3]. These sensor nodes are capable of capturing various physical properties, such as temperature, pressure, motion of an object, and many more. These abilities of sensor nodes make possible to understand the different aspects of the environment. A Wireless Sensor Network (WSN) [4-9] is a group of sensor nodes, which execute some monitoring task in a collaborative and autonomous manner. There are many applications and their working environment which may restrict the use of wired networks, infrastructure based wireless networks, and ad-hoc networks.Wireless sensor network is an important supplement of the modern wireless communication networks. It can be viewed as a network consisting of hundreds or thousands of wireless sensor nodes which collect the information from their surrounding environment and send their sensed data to remote control center which is called Base Station (BS) or sink node. Each sensor node is capable of sensing, processing, communication, etc.

II. RELATED WORK

2.1 Wireless sensor networks

A Wireless Sensor Network (WSN) is a group of sensor nodes, which execute some monitoring task in a collaborative and autonomous manner. Wireless Sensor Networks (WSN) is capable of data collection,

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aggregation and communication from a remote environment through many distributed individual sensor nodes (motes) which uses radio link to communicate

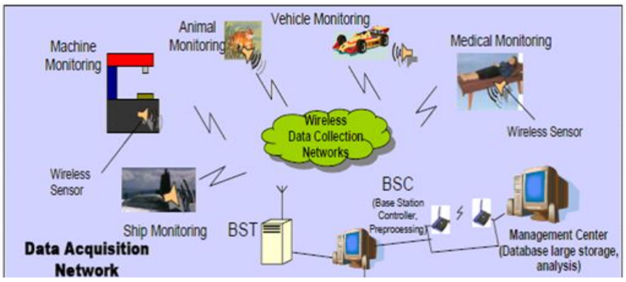

Fig.2.1 : Shows a typical sensor network example

Fig.2.1 shows a typical sensor network example. Sensor nodes may be randomly deployed (e.g. dropped from airplane) in an environment or may be positioned as per need and situation. These sensors will gather information which can be further aggregated and then sent to a BS through direct transmission or multi-hop transmission. Finally, the BS will analyses the collected information from sensors and make reasonable deduction or prediction about the event which has happened or is likely to happen in the sensor network.

2.1.1 Sensor node architecture

Fig.2.2 shows the sensor node architecture on a sensor board [4][5]. Normally, each sensor consists of four main components, namely sensing unit, processing unit, transmission unit and power unit. It may have two additional components, as per need, which is position finding system and mobilizer

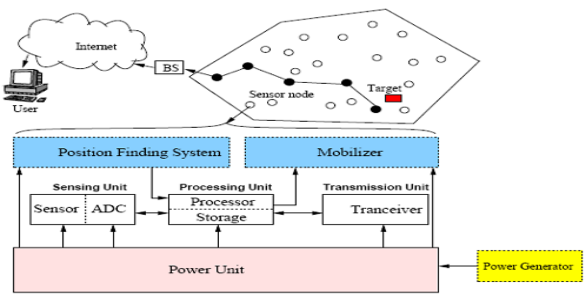

Fig.2.2 : Sensor node architecture

III. Proposed Localization Scheme

we are proposing a Localization scheme based on Energy Band. Energy Band Based Localization works on static clusters formed on the basis of energy band. It achieves evenly distributed Cluster throughout the target area. As size of cluster decrease we are able to assign unique coordinates to any nodes in the target area.

3.1 Mathematical Model of Energy Band Based Localization Scheme

First we will discuss number of reference nodes required to uniquely determine the position of a node. If the Base Station (BS) knows the range of one neighbor node (N1) the position can be anywhere on a circle with radius equal to the range (r1) between them. But when a second reference Grid Node is added a second circle (r2) intersects the first and the solution is the two points (A and B) as shown in Fig. 3.1.

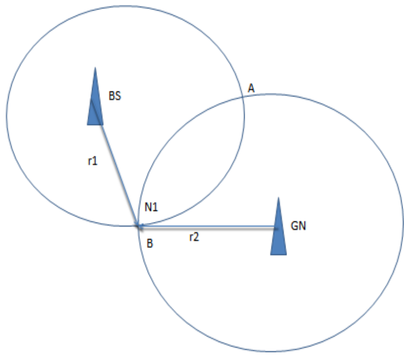

Fig. 3.1 : Position finding by BS and GN (Lateration)

So for uniquely determining the position in 2D a third assistant node is required and only one solution (A) remains, as seen in figure 3.10 (Trilateration). Some special cases exists where three references is not enough in 2D. This can be when the references are perfectly aligned or in the same point. These circumstances are not very likely in real world scenarios.

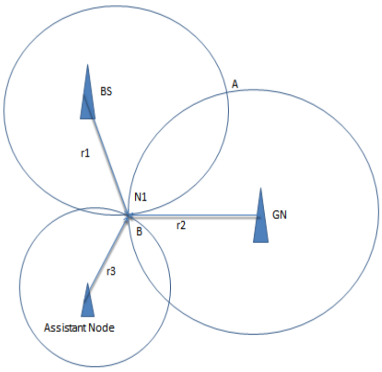

Fig. 3.2 : Position finding by Trilateration

For a 3D position four references is needed. The first reference gives a sphere, and the second sphere intercepts the first one and results in a circle. A third reference reduces the possible solution to two points on the circle, which in some cases might be enough. The GPS only need signal from 3 satellites to estimate the position on earth, the second solution will either be in space and or beneath the earth's crust is not likely the correct one. If no knowledge about the scene is present a fourth reference is needed to uniquely estimate the position.

In our Energy Band based Localization Scheme BS and GD are located outside the target area. So that the entire sensor nodes will lie on one side of target area as shown in Fig. 3.3. Hence we can use literation method to estimate the location of nodes.

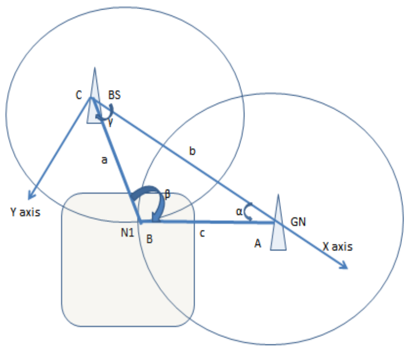

Fig.3.3 : Coordinate finding by literation

Let us consider a simple case of two known points and the range to a unknown position the problem is solved using Law of Cosines. In figure 3.3 the position of point A and C and the sides of triangle a, b and c are known. By using the Law of Cosines the angle α can be found, equation 4.1.

$$c^2 = a^2 + b^2 - 2ab\cos\alpha$$

$$\Rightarrow \quad \cos\alpha = \frac{a^2+b^2-c^2}{2ab}$$

$$\Rightarrow \quad \alpha = \cos^{-1}\left(\frac{a^2+b^2-c^2}{2ab}\right)$$

………………eq. (4.1)

If we attach a reference frame to BS so that X axis lies along the line joining BS and GN, Y axis lie perpendicular to X axis and passing through origin at BS as shown in Fig. 3.3. So coordinates of unknown node will be ($a\cos\gamma, a\sin\gamma$).

3.2 Energy Band Based Localization Scheme

Energy Band Based Localization uses the Base Station (BS) and Grid Node (GN) to eliminate the need of position finding system like GPS for estimating the distance between nodes and also between a node and BS. It consists of following steps

1. Base Station Realization
2. Grid Node Realization
3. Node Realization
4. Formations of Logical Energy Bands and Clusters
5. Determination of virtual coordinate

(1). Base Station Realization:

Consider a wireless sensor network scenario as shown in Fig.3.4. There is a base station (BS), Grid Node (GN) and a number of sensor nodes deployed randomly in the given target area. Initially the base station broadcasts a message containing its identification at a certain power say **P** as shown in Fig. 3.5. This message basically makes each node aware of the base station to which it is supposed to communicate. This process is called **base station realization** as shown in Fig.3.5. Here each node receives that message with different power because of transmission loss, fading etc. For instance, let the power received by the node **n** is $\mathbf{P_{nb}}$. Hence, the transmission loss between the base station and the node **n** is ($\mathbf{P} - \mathbf{P_{nb}}$). So, when the sensor node needs to send a packet to the Base Station, it should transmit with the power (**P - P_{nb} + P_h**) where '**P_h**' is the minimum power at which any node can receive a healthy signal for regeneration. This is a one-time process and needs to be repeated only if new nodes are introduced.

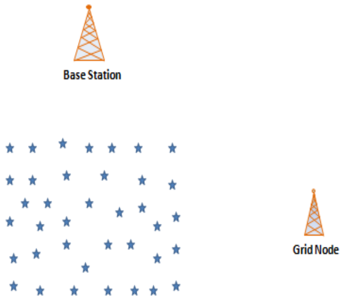

Fig.3.4 : Deployment of sensor nodes

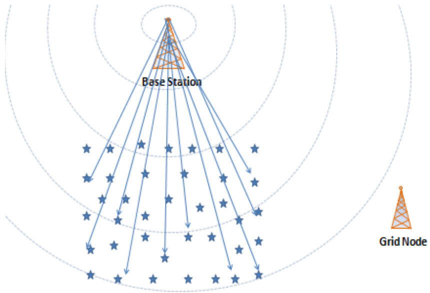

Fig.3.5 : Base station Broadcasts message

(2). Grid Node Realization: Grid Node (GN) is a kind of temporary base station which is used for creating bands along Y axis. For this purpose GN also broadcasts a message of same power **P** that is received by each node with different power. For instance, let the power received by the node **n** is **P_{ng}** This process is called is called **grid node realization process** and is shown in Fig. 3.6. This is also a one-time process and GN is not required henceforth. Hence, GN may not be a permanent station.

(3). Node Realization: Now each node sends received signal strength of BS and GN along with its id i.e., (**id, P_{nb}, P_{ng}**) to BS. This process is called **node realization process** as shown in Fig. 3.7. This information is used by BS to create logical band in X direction as well as in Y direction. Further, the value of **P_{nb},** and **P_{ng}** is used by BS to calculate distance of each node from BS and GN respectively.

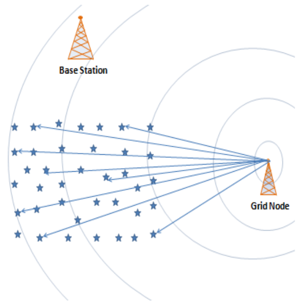

Fig.3.6 : Grid Node Realization

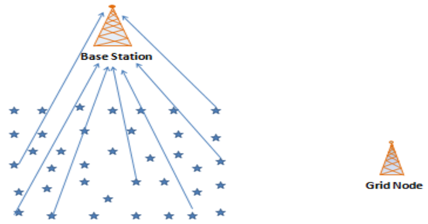

Fig.3.7 : Node Realization

(4). Formation of logical Energy Bands and Cluster: After the node realization process, the base station is aware of received signal strength **P_{nb}** and **P_{ng}** from BS and GN respectively for each node. BS puts that node into **Level 1** for which received signal strength **P_{nb}** is maximum. Similarly nodes whose received signal strength is minimal will lie on last **Level N**. Now the BS logically divides the target area into smaller region along **Y** axis as shown in Fig.3.8 and forms a logical energy band of the complete scenario. BS allocates same Band ID (**BIDy**) to those nodes that lie on same band along **Y** direction. Similarly the value of **P_{ng}** of each node helps partition of target area along **X** axis (Fig.3.9) and Band ID (**BIDx**) is allocated to each nodes along **X** direction. The nodes having same **BIDx and BIDy** will lie on same cluster as shown in Fig.3.10. The numbers of band along **X** direction and **Y** direction depends on size of target area and density of nodes in target area. This process is known as **logical distribution of nodes into cluster.** As distance between levels decreases, size of cluster also decreases and each node is uniquely associated with a cluster having co-ordinate (BIDx, BIDy). So accuracy in localization increases as we decrease size of cluster.

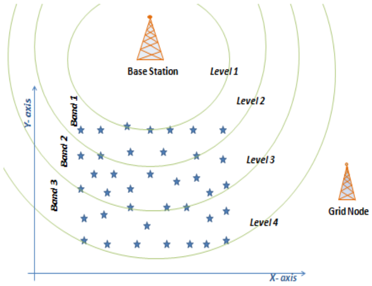

Fig.3.8 : Creation of levels and Band according

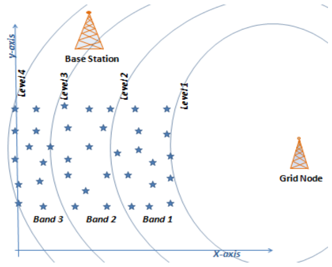

Fig.3.9 : Creation of levels and Band to BS according to GN

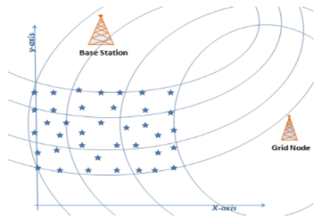

Fig. 3.10 : Formation of cluster

(5). Determination of virtual coordinate: A number of nodes in a cluster depend on the size of cluster and density of nodes in target area. Since, each node within cluster will have same BIDx and BIDy, it is proposed to have clusters of small size so that each cluster contains only one node and can be uniquely identified by its virtual coordinates. Hence, accuracy of determination of virtual coordinate is inversely proportional to size of clusters.

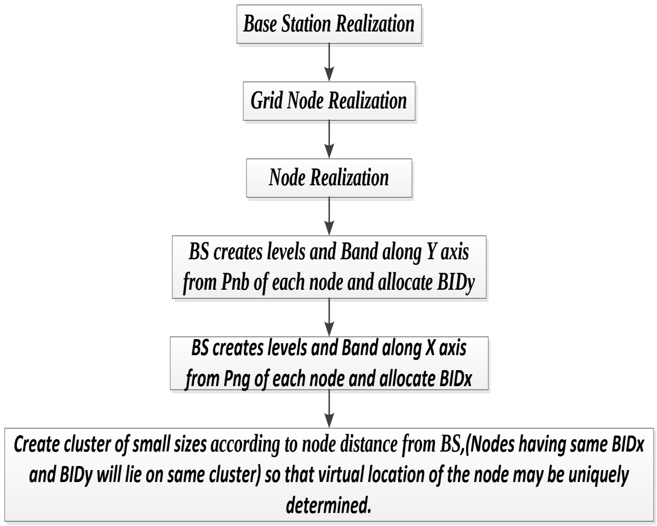

Fig.3.11 : Process of Cluster Setup Phase

Algorithm 3.1: Cluster setup phase

1: Base station realization
2: Grid node realization
3: Node realization
4: BS creates levels and bands along X axis and Y axis
5: BS allocates BIDx and BIDy of each node.
6: Create clusters having CID 1to N
7: Create S-list for each cluster.
8: Transmission of control packet to each node.
9: Assign virtual coordinates to each node.

The setup phase ends after the entire target area is divided into energy band and finally into clusters based on energy band of optimal size.

IV. Analysis and comparison

4.1:position of First Dead Nodes: After analysis of simulation result of EBBCP, we found that position of first dead nodes satisfy following conditions.

(A). It may be a CH of that cluster whose distance is farthest from BS

(B). It may be a CH of that region where density of nodes is minimum so that it has less chance of CH rotation.

This has been verified by simulation and one instance of the result showing first dead node can be seen in Fig.4.1.

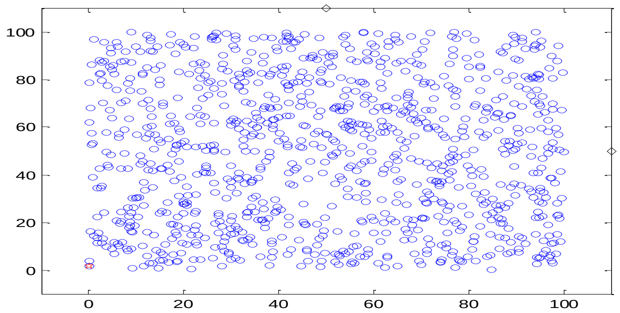

Fig.4.1 : Shows position of First Dead nodes in Red Color in EBBCP

4.2: Distribution of Half dead nodes: The CH rotation policy of EBBCP based on **S-list** and the shape of cluster formation for this protocol has resulted in dead node pattern as shown in Fig.4.9. It shows Dead nodes that are lying at the boarder of clusters towards BS as the nearest node gets first chance to become CH both times and remains CH till death in the second chance. Further, it can be visualized that number of dead nodes in a region is directly proportional to distance of the region from BS which has resulted in denser dead nodes at the lower part of Fig.4.2

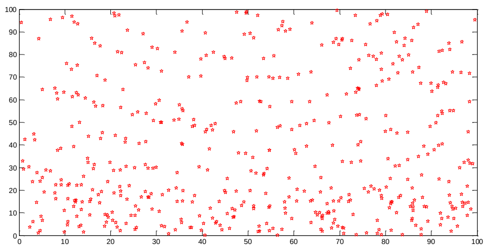

Fig.4.2 : Shows distribution of Half Dead Nodes in EBBCP

4.3 : Performance of EBBCP for different position of BS: We have analyzed performance of EBBCP for different position of BS keeping in view parameters like (a) Numbers of alive nodes, (b) Total packet received by BS and (c) Network Remaining energy for different values of D from 10 m to 40m at an interval of 10 meters as shown in Fig.4.3, Fig.4.4 and Fig.4.5.

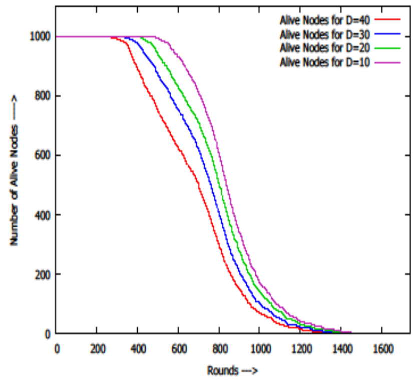

Fig.4.3 : Number of Alive nodes

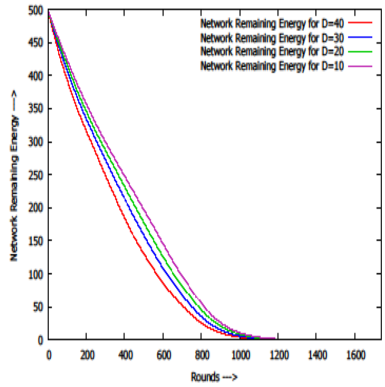

Fig.4.4 : Network Remaining energy

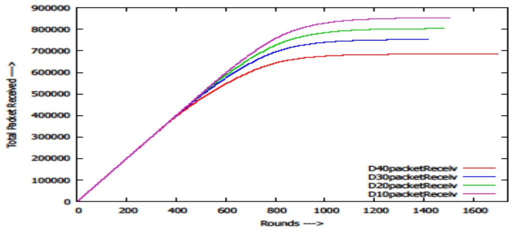

Fig.4.5 : Shows Total packet received by BS in EBBCP for Different value of D

4.4 Comparison between EBBCP and LEACH

The new protocol EBBCP was compared with LEACH for the value of **P = 0.1** where **P** is the probability of a node becoming CH in current round. This value of **P** is chosen so that the number of clusters formed for the target area is similar. The result obtained for the said comparison for number of alive nodes may be seen in Fig.4.13 which Shows that EBBCP performs better than LEACH throughout the network lifetime. The difference in performance increases with number of rounds in the favor of EBBCP. The various simulation results for EBBCP and LEACH are summarized in Table 4.2.

Table 4.1 : Shows First, Half and Full Dead round of EBBCP and LEACH

	Energy Band Based Protocol				Low-Energy Adaptive Clustering Hierarchy			
D	First Dead	Half Dead	Full Dead	Total Packet Received	First Dead	Half Dead	Full Dead	Total Packet Received
0	483	873	2141	903217	468	527	665	530991
10	448	829	1883	861243	443	510	700	514391
20	388	769	2144	811847	432	492	621	494984
30	263	700	1583	753029	424	469	564	472646
40	226	660	1668	703453	405	445	522	447600
50	176	593	1397	637860	381	419	549	420664

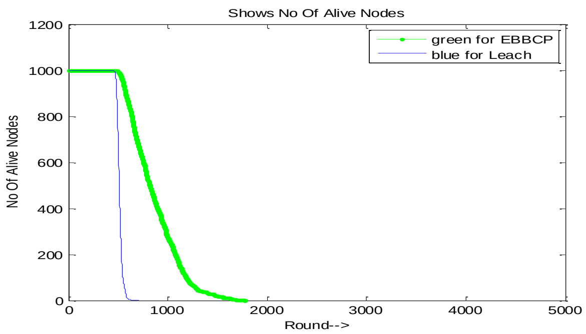

Fig.4.6 : Shows Numbers of Alive Nodes in EBBCP and LEACH per round

The results obtained using EBBCP for network remaining energy and total packet received was compared with LEACH and their comparative performance is shown in Fig.4.14 and Fig.4.15 respectively. The results show that EBBCP outperforms LEACH by a good margin on both parameters.

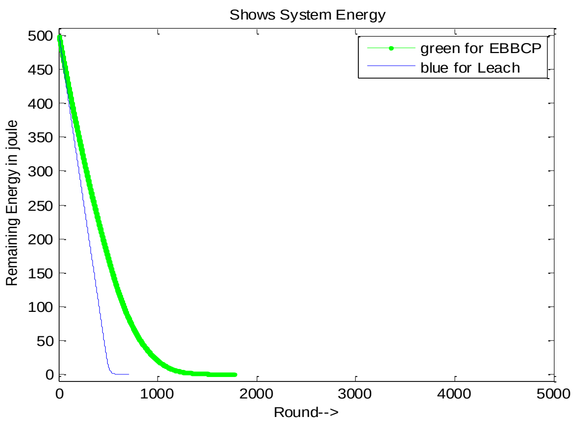

Fig.4.7 : Comparison of Network Remaining Energy in EBBCP and LEACH

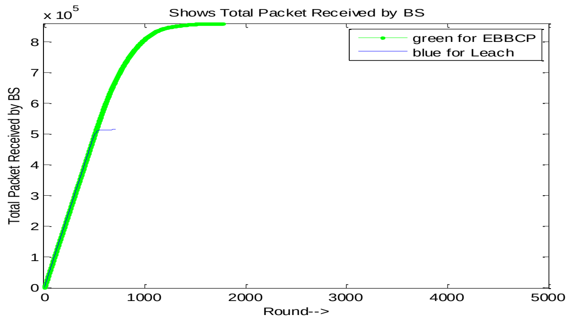

Fig.4.8 : Comparison of Total Packet Received by BS in EBBCP and LEACH

V. Conclusion

Energy is a crucial factor that affects the performance of a wireless sensor network. Given algorithm save the energy and increases the total number of packets that are finally delivered to the base station thus increasing the throughput with remaining energy. Along with this it also increases the lifetime of the network and reduces the number of dropped packets. The percentage of the higher priority packets received at the base station also increases.

The above said improvements resulted in some more energy saving directly resulting in better performance for EBBVCP as compared to EBBCP and LEACH on parameters like total packet received , network remaining energy and No of Alive node as expected

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Cite this article as :

Rakesh Ranjan, Amit Kumar, "An Energy-Efficient Routing Protocol Based on Energy Band and Virtual Localization", International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN : 2456-3307, Volume 7 Issue 2, pp. 184-191, March-April 2021. Available at

doi : https://doi.org/10.32628/CSEIT217245

Journal URL : https://ijsrcseit.com/CSEIT217245