"VELOCITY ENERGY-EFFICIENT AND LINK AWARE CLUSTER-TREE (VELCT) BASED DATA COLLECTION FOR WIRELESS SENSOR NETWORKs"

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Abstract - ***- Topology management plays a vital role in reducing various constraints such as limited energy, node failure, computational resource crisis, long-range communication with in a network, communication failure, delay, traffic, etc. Likewise, the topology inherently defines the types of routing path, as unicast or broadcast and it determines the size, type of packets and other overheads. Choosing a right topology helps to enhance the performance, coverage, lifetime of the network and QoS of the network. An efficient topology ensures that neighbours are at a minimal distance and reduces the probability of a packet being lost between sensor nodes. One very important parameter that plays a major role in the performance of WSNs is energy consumption. Energy consumption is directly related to the transmission distance between the sensor nodes. Data aggregation protocols can reduce the communication cost, thereby extending the lifetime of sensor networks. Prior works on data aggregation protocols have focused on tree-based or cluster-based structured approaches. Although structured approaches are suited for data gathering applications, they incur high maintenance overhead in dynamic scenarios for event-based applications. The designed VELCT scheme minimizes the energy exploitation, reduces the end-to-end delay and traffic in cluster head in WSNs by effective usage of the DCT. The strength of the VELCT algorithm is to construct a simple tree structure, thereby reducing the energy consumption of the cluster head and avoids frequent cluster formation.***

Index Terms*- VELCT,* ***data collection tree, data collection node, cluster tree, wireless sensor networks.***

1.INTRODUCTION

Wireless sensor network (WSN) is widely considered as one of the most important technologies for the twenty-first century. In the past decades, it has received tremendous attention from both academia and industry all over the world. A WSN typically consists of a large number of low-cost, low-power, and multifunctional wireless sensor nodes, with sensing, wireless communications and computation capabilities [1]. These sensor nodes communicate over short distance via a wireless medium and collaborate to accomplish a common task, for example, environment monitoring, military surveillance, and industrial process control. The basic philosophy behind WSNs is that, while the capability of each individual sensor node is limited, the aggregate power of the entire network is sufficient for the required mission.

In many WSN applications, the deployment of sensor nodes is performed in an ad hoc fashion without careful planning and engineering. Once deployed, the sensor nodes must be able to autonomously organize themselves into a wireless communication network. Sensor nodes are battery-powered and are expected to operate without attendance for a relatively long period of time. In most cases it is very difficult and even impossible to change or recharge batteries for the sensor nodes. Unreliability of sensor nodes, and sever power, computation, and memory constraints. Thus, the unique characteristics and constraints present many new challenges for the development and application of WSNs [2]. Due to the severe energy constraints of large number of densely deployed sensor nodes, it requires a suite of network protocols to implement various network control and management functions such as synchronization, node localization, and network security. The traditional routing protocols have several shortcomings when applied to WSNs, which are mainly due to the energy-constrained nature of such networks. For example, flooding is a technique in which a given node broadcasts data and control packets that it has received to the rest of the nodes in the network. This process repeats until the destination node is reached. Note that this technique does not take into account the energy constraint imposed by WSNs. As a result, when used for data routing in WSNs, it leads to the problems such as implosion and overlap. Different topologies of WSNs are identified. In doing so, different application protocols proposed by various researchers, such as protocols for data gathering/collection, target tracking, routing, data aggregation, data dissemination, etc., are studied. These protocols use various types of logical topologies. From each of the protocols.

The identified topologies are (i) flat topology, (ii) chain-based topology, (iii) cluster-based topology and (iv) tree-based topology

1.1 Flat/Unstructured Topology:

This is actually the case of no topology or the absence of any defined topology. In flat topology, each sensor plays equal role in network formation. Different protocols have been proposed based on flat/unstructured topology [3]. For example, this flat topology has been used in data aggregation protocols, data gathering protocols, node scheduling protocols, and routing protocols. Figure 1.5 shows the flat topology architecture where the nodes are the sensors and the edges are available communication links between two sensors. All the protocols, while using flat topology, attempt to find good-quality routes from source nodes to sink nodes by some form of flooding. Flooding is a technique in which a given node broadcasts data and control packets that it has received to the rest of the nodes in the network. This process repeats until the destination node is reached.

1.2 Chain-Based Topology:

In this topology, the protocols construct transmission chain(s) connecting the deployed sensor nodes to save energy dissipation of data transmission. A leader is selected in a chain that acts as the sink. All sensor nodes communicate with each other along the chain. A node sends data to the next node, which is called successor node of the former node, towards the leader node. A successor node, receiving data from the Predecessor node, forwards the data to its successor node towards the leader. In this fashion, all sensor nodes send their sensed data to the leader node(s) [4]. This way of communication facilitates the data aggregation. PEGASIS is an example protocol based on chain topology. In PEGASIS, every node in chain senses the data, receives data from its predecessor, fuses with received the predecessor's data and transmits to next node in chain. Data aggregation performs in-network fusion of data packets, coming from different sensors en-route to the base station, in an attempt to minimize the number and the size of data transmissions and thus save sensor energy.

1.3 Cluster-Based Topology:

Cluster-Based topologies have widely been used in WSNs for various types of protocols, such as data gathering, target tracking, one-to-many, many-to-one, one-to-any, or one-to-all communications, routing, etc. Clustering is particularly useful for applications that require scalability to hundreds or thousands of nodes. Scalability in this context implies the need for load balancing, efficient resource utilization, and data aggregation. The Clustering Process: During the establishment of the cluster, it is necessary to take into account aspects like: cluster size and form, how to select the cluster head, how to control inter-cluster and intra-cluster collisions, and energy saving issues. Different approaches exist to implement each one of these stages [5]. For example, it is possible to use a fixed distribution of the SN and the CH, or to use a dynamic algorithm for the location of the sensors and the CH election. Clusters may be formed in any one of the following ways: Probabilistic Method: LEACH protocol uses this method where each sensor randomly picks a real number from 0 to 1. If the number is greater than a threshold value, the sensor declares it as a cluster leader and broadcasts invitation messages to all other sensors. A sensor, not picking a real number greater than threshold s any one of the leaders. Thus clusters are formed. By Election Phase: In this method all the sensors broadcast their information to all other sensors and form a knowledge base. Based on the local knowledge they form cluster and then select a leader.

1.4 Tree-Based Topology:

In this topology, all the deployed sensors construct a logical tree. Data are passed from a leaf node to its parent nodes. In turn, a receiver node receiving data from the child node sends data to receiver's parent node after aggregating data with its own data. In this fashion, data flow from leaf nodes to the root node, which generally acts as the sink [6]. The idea behind constructing logical tree is that it avoids flooding and data can be sent using unicast instead of broadcast. This way the topology can save energy. Figure 1.8 shows a typical formation of logical tree. The arrows show the data flow from a leaf node to the root node/sink.

1.5 Cluster Tree Topology (CTT):

CTT holds clusters and tree topology, then the topology design starts with a special node called DD (Designated Device). It acts as a cluster head with greater transmission power and receiver sensitivity[7]. The beacon signal contains NetID (Identity of the Network), CID (Cluster Identification) and NID (Node Identification) nodes which are added to the DD. Then, the CONNECTION REQUEST and CONNECTION RESPONSE are used to create a cluster tree based on the beacon reception of the sensor node from a neighbour sensor node. Here, the CTT creation with node id is a tedious process. Because the DD should be initiated to construct a cluster tree. The major goal of cluster tree is to reduce the energy exploitation, end-to-end delay and improve the capacity of WSNs. Hence proposed CTDGA (Cluster-Tree Data Gathering Algorithm) to gather the data from sensor nodes with minimum energy consumption.

2. PROBLEM OF STATEMENT

The existing WSN topologies include flat, tree, cluster, chain and hybrid. Based on the nature of network, various topologies are followed to obtain the maximum data collection. The FT (Flat Unstructured Topologies) designed to static WSNs, and there is no predefined topology to transfer the data from the sensor nodes to sink. All the sensor nodes directly communicate with the sink or simply forwards the data packets to the one-hop neighbor nodes and finally reach to the sink. The existing methods have limitation such as delay, node failure, data redundancy and large amount of energy utilization, since;

it is using flooding, gossiping, direct communication, etc., to communicate between the nodes. It is the main drawback of this topology and not recommended to mobile WSNs. Chain topology offers better performance than the flat topology, but it also has the following demerits viz. delay, node failure and energy exploitation. Because of such limitations in chain topology, that is not mended to adapt mobility-based WSNs. The data dissemination from cluster head to cluster head or sink (i.e., direct-hop or multi hop) requires reliable stable links, which causes more energy consumption. Tree based topology can save more energy than cluster and chain based topology. It includes several time stamps in order to collect data from leaf to root node. In mobility environment, it leads to link failure, packet drop and delayed transmissions. It is observed that the hybrid topology can offer better performance than the existing single topologies. CTT is a hybrid method, and that can offer enhanced performance than aforementioned topologies. However, the cluster head selection and cluster maintenance under mobile sensor environment is a costly operation. The above topologies become probably infeasible and cannot be adapted to mobile sensor ambiance.

3. PROPOSED SYSTEM

In this proect propose a novel logical topology for data collection, named, Velocity Energy-efficient and Link aware Cluster-Tree (VELCT). It is an enhanced version of CIDT, which mitigates the existing issues in CIDT such as coverage, mobility, traffic, tree intensity and delay of the tree structure. Scheme which helps to improve the network lifetime and executes effective data collection there by increasing the network lifetime with minimum delay. VELCT is an efficient hybrid scheme suitable for dense wireless sensor networks than any other logical topology. On mobility-based environments, it provides better performance than other methods. The VELCT scheme consists of **set-up phase** and a steady state phase. In the set-up phase, cluster formation and data collection tree construction is initiated to identify the optimal path between cluster member and sink. It is denoted in intra cluster and DCT communication. Then, the **steady-state phase** is initiated to transfer the data from the cluster members to the sink. Fig 1 shows the simple outline of proposed scheme named into VELCT structure. It is a unique nature of logical scheme, which helps to improve the network lifetime and executes effective data collection thereby increasing the network lifetime with minimum delay. VELCT is an efficient hybrid scheme suitable for dense wireless sensor networks than any other logical topology. On mobility-based environments, it provides better performance than other methods.

A) SET-UP Phase

Set-up phase carry out with the intra cluster communication and DCT communication operations. In an intra cluster communication all the sensor node elects the cluster head with threshold value, and forms a cluster with better connection time, RSS, coverage time and robustness for connection. After the intra cluster communication, DCT communication is initiated to collect the data from its cluster head and then forwards the aggregated data packet to the sink. Let all the cluster head to be connected with DCN, and all the DCN connected with sink which constructs the DCT.

Intra Cluster Communication: Considering ambiguous large-scale WSNs, sensor nodes have been densely deployed over the region. During the set-up phase, the beacon signal is used to identify the sensor nodes location and position. Once the nearby nodes are identified, cluster head election algorithm is used to elect the cluster head. Now, the cluster head selection is based on the threshold value $U^{n}_{\vartheta\omega}$, connection time $\Delta D^{n}_{\vartheta\omega}(t, t+s)$, coverage time $\Delta I^{n}_{\vartheta\omega}(t, t+s)$and robustness for connection $\Delta G^{n}_{\vartheta\omega}$.After the cluster head election, the next phase DCT formation is initiated. Threshold value $U^{N}_{\Theta\omega}$ has been calculated in Equation (2) by adding the flag value with the multiplication of factors such as the total number of neighbor nodes, residual energy, current speed and current coverage distance of the sensor node. Let F_C Is the flag (set, $F_C = 1$ for previous round cluster head and $F_C = 0$ for sensor node having a chance to act as current round cluster head based on $U^{N}_{\Theta\omega}$.

$$U^{n}_{\vartheta\omega} = F_c + \left(\frac{N^{c}_{\omega}}{N^{m}_{N} - N^{c}_{\omega}} \times \frac{E^{m}_{N} - E^{c}_{\omega}}{E^{m}_{N}} \times \frac{V^{m}_{N} - V^{c}_{\omega}}{V^{m}_{N} + V^{c}_{\omega}} \times \frac{R^{m}_{N} - R^{c}_{\omega}}{R^{m}_{N} + R^{c}_{\omega}} \right) \quad \text{.......(2)}$$

N^{C}_{ω} is the number of cluster members on this round,$E^{c}_{\omega}$is the current sensor node energy, $V^{c}_{\omega}$is the current speed of the sensor node, R^{c}_{ω} is the current coverage radius of the sensor node, N^{m}_{N} is the maximum number of cluster members on each round, E^{m}_{N} is the initial energy, $V^{m}_{N}$is the maximum speed of the sensor node $R^{m}_{N}$is the maximum coverage radius of the sensor node.

$(R^{m}_{N} - R^{c}_{\omega})/(R^{m}_{N} + R^{c}_{\omega})$ is considered to elect the cluster head with maximum coverage distance N^{C}_{ω} is the derivative from the expected number of sensor nodes $M_e$or current number of sensor nodes M_c in each cluster and that is denoted in Equation (3) and (4) . Those nodes having maximum number of cluster members, residual energy, RSS and connection time can be elected as cluster head.

$$M_c = M_e - (M_n + M_d + M_s) \quad \text{.......(3)}$$

$$M_e = N_c - C_H - C_T/C_H \quad \text{........(4)}$$

$M_c$is the current cluster member from one cluster, M_e is the expected number of cluster member, M_n is the newly ed cluster member from neighbour cluster on this round, M_d is the number of cluster member on dead, M_s is the total number of cluster member on sleep state, N_c is the total number of current sensor nodes Let $[D^{\omega}_{\vartheta\omega}(t)$be the distance between cluster head and cluster member at any time instance t given by

$$[D^{\omega}_{\vartheta\omega}(t)]^{2} \geq [(X_w - X_v)^2 + (Y_w - Y_v)^2] \quad \text{......(5)}$$

At time t = 0, each sensor node receives an advertisement message from any one of the cluster heads, Equation (5) is considered and simplified into

$$[D^{\omega}_{\vartheta\omega}(t)]^{2} \geq [(x_w - x_v)^2 + (y_w - y_v)^2] \text{ift=0} \quad \text{.......(6)}$$

Now, the connection time $\Delta D^{w}_{\vartheta\omega}(t, t+s)$ is the difference between $D^{w}_{\vartheta\omega}(t)$ and $D^{w}_{\vartheta\omega}(t+s)$ at time instance t and t+s. Let $\Delta D^{w}_{\vartheta\omega}(t, t+s)$ can be found from Equation (7)

$$\Delta D^{w}_{\vartheta\omega}(t, t+s) = D^{w}_{\vartheta\omega}(t) - D^{w}_{\vartheta\omega}(t+s)$$
$$\text{if}(n,s) \epsilon\ t, 0,1,2,3 \ldots, n \qquad \ldots\ldots(7)$$

For $\Delta D^{w}_{\vartheta\omega}(t, t+s) = 0$, there is no sensor nodes on mobility with in a cluster, $\Delta D^{w}_{\vartheta\omega}(t, t+s)$ is a negative value for sensor nodes in a cluster moving away from the cluster head, $\Delta D^{w}_{\vartheta\omega}(t, t+s)$ is a positive value for cluster head and cluster member moving towards to each other. Now, the RSSI (Received Signal Strength Indicator) value I can be calculated at any time instance t and t + s in Equation (9)

$$I^{\omega}_{\vartheta\omega}(t) = I^{c}_{\vartheta\omega}(t) - I^{m}_{\vartheta\omega} \qquad \ldots\ldots(8)$$
$$I^{\omega}_{\vartheta\omega}(t+s) = I^{c}_{\vartheta\omega}(t+s) - I^{m}_{\vartheta\omega} \quad \forall_s \in t \qquad \ldots\ldots(9)$$

Coverage time $\Delta I^{\omega}_{\vartheta\omega}(t, t+s)$is the difference between $I^{\omega}_{\vartheta\omega}(t)$ and $I^{\omega}_{\vartheta\omega}(t+s)$which can be found using Equation (10)

$$\Delta I^{\omega}_{\vartheta\omega}(t, t+s) = I^{\omega}_{\vartheta\omega}(t) - I^{\omega}_{\vartheta\omega}(t+s) \ \forall_s \in t \qquad \ldots\ldots(10)$$

$\Delta I^{\omega}_{\vartheta\omega}(t, t+s) \leq 0$, the cluster member is moving away from the cluster head $\Delta I^{\omega}_{\vartheta\omega}(t, t+s) \geq 0$, the cluster member is moving towards the cluster head. The sensor node ϑ checks $G^{n}_{\vartheta\omega}$with one-hop neighbor node ω to choose an optimal cluster head on every round. The dimensionless value $\delta^{w}_{vw}, \xi^{w}_{vw}, \eta^{w}_{vw}$ and $k^{w}_{vw}$is a linear combination with constant coefficients between 0 and 1. The coefficients represent the consequence of each factor and are denoted in equation (11)

$$\delta^{w}_{vw} + \xi^{w}_{vw} + \eta^{w}_{vw} + k^{w}_{vw} = 1 \qquad \ldots\ldots(11)$$

Therefore, the above Equation (11) can be originated into Gn ϑ_ and in Equation (12) represented as

$$G^{n}_{\vartheta\omega} = \left(\delta^{w}_{vw} \times \frac{E^{m}_{N} - E^{c}_{\omega}}{E^{c}_{\omega} \times N^{C}_{w}}\right) + \left(\xi^{w}_{vw} \times \left(1 - \frac{I^{m}_{vw}}{I^{c}_{vw}}\right)\right) + \left(\eta^{w}_{vw} \times \frac{d_{wv} - D^{\omega}_{v\omega(t)}}{E^{c}_{\omega} \times N^{C}_{w}}\right) + \left(k^{w}_{vw} \times \frac{\Delta t^{\omega}_{v\omega}}{t^{f}_{c}}\right) \qquad \ldots\ldots(12)$$

E^{m}_{N} is the initial energy, $E^{c}_{\omega}$is the current energy of cluster head, $N^{C}_{w}$is the number of current cluster members for cluster head w, I^{m}_{vw} is the minimum required RSSI value from ϑ and w, I^{m}_{vw} is the current RSSI value between ϑ and $D^{\omega}_{v\omega(t)}$ is the distance between ϑ and w at any time instance t, $d_{wv}$is the maximum coverage distance between w and ϑ. $\Delta t^{\omega}_{v\omega}$ is the estimated connection time for ϑ begins its transmission to w t^{f}_{c} is the current duration of the data frame for w.

DCT Communication: The DCT communication phase starts with intra cluster communication phase. In an intra cluster communication process, a sensor node elects itself as a cluster head to form a cluster, then the cluster head is responsible to collect the data from its cluster members and cluster maintenance operations (e.g., data aggregation/data fusion). Thereafter, tree formation is initiated, which connects the cluster head and sink. Now, the sink initiates the DCT formation process. Based on the location of cluster head and connection time, a few nodes are selected as DCN (Data Collection Node) to generate DCT. It is represented in DCT onstruction algorithm. However, it does not participate in sensing and is not a part of any cluster on that particular round therefore it may act as an ordinary sensor node. In this case, the selection of DCN does not affect the data collection of a corresponding cluster. It should have better connection time with the nearest DCN and cluster head.

Data Collection Tree Formation: DCT is a hierarchical tree structure, which uses DCN to collect the data from the cluster heads and deliver it to sink, and that covers to the whole WSNs. Here, the sink selects the DCN based on the threshold value, connection time, RSS, communication range and heftiness for connection, which reduces the surplus energy usage and traffic of the whole network. While the sensor nodes are on high mobility, the above selected DCN can keep the communication with the cluster head for a longer time and there is no need to update in the tree structure. In order to keep the lifetime of whole network in harmony new DCN is selected every time when the new cluster heads are elected (i.e., the new cluster head and DCN selected on every round). New DCN selection also is carried out by the sink, which is based on the mobility of the new cluster head. The DCN collects the data from cluster head, aggregates the data (i.e., drops duplicated information) and then forwards it to the next DCN. The DCT construction algorithm is executed by sink in order to select the DCN to form an independent tree structure.

DCT Construction: Initially the sink starts to find a first DCN from one-hop distance neighbour nodes to add that particular node in DCT. The parameters include HC = 1 (i.e., HC is the Hop Count or Hop distance) is used to select the CNI that is one-hop distance Neighbour Node (NN) from sink or DCN. NHC (Next Hop Count) is an additive value, which denotes that one-hop distance SN from the NN (i.e., NHC = ++HC), and it is used to identify the cluster head from NN. Let NN is the one-hop distance SN from the sink, and NH (Next Hop) is the next one-hop distance SN from the NN. Then, the identified NN have been considered into CNI (Current Node Identity). In that case, the one hop distance NN is found to be CH, then skip that particular node and hand over to select another node (i.e., HC = 1, NN) from the sink or DCN as CNI (Current Node Identity). The sink or DCN verify the parameters such as threshold U, connection time _D, coverage time _I and robustness connection G. After the parameter verifications, the sink selects a node with optimum value from CNI and assigns the node integrity into TIN (true identity number). Now, the DCN is selected from the TIN then the DCN selection is finalized, afterward DCN calculates the frame duration $t^{f}_{DCN}(0)$. After the DCN validation, the node checks the network traffic or frame duration $t^{f}_{DCN}(E)$ with MFD (Maximum Frame Duration). In the case of MFD > $t^{f}_{DCN}(E)$, the selected DCN can be utilized to generate a DCT Or else, the sink skips to discover a new DCN and then starts to generate a new DCT. Once the first DCN is selected, then the next DCN discovery starts from the first DCN instead of sink. Consequently, the DCN selects another one-hop distance neighbour node to act as a CNI. Thereafter, TIN and DCN selection process is initiated to identify the next one-hop distance DCN. DCN selection is expanded to generate the DCT to connect all of the cluster heads in the WSNs.

B) Steady State Phase

Once the set-up phase completed, steady-state phase is initiated. In steady-state phase, all the cluster members send the collected data to the cluster head in allocated time slots. Then, the cluster head starts to collect and aggregate the data from its cluster members. Meanwhile, the DCT communication is initiated, which uses Direct Sequence Spread Spectrum (DSSS) to transfer the data from the cluster head to DCN and then the sink. Here, the DCN collects and aggregates the data from the corresponding cluster head or DCN.

C) Software Requirements Specification (SRS)

It is a perfect description of the conduct of the organization that is to be prepared. The use Case technique can be applied in order to find functional requirements of the software product [13]. The SRS also includes non-working (or supplementary) requirements. Non functional requirements are requirements which impose constraints on the conception or execution (such as performance engineering requirements, quality standards, or design constraints) [13]. Software design is a procedure by which the software demands are transformed into a representation of software elements, interfaces, and information necessary for the implementation stage. The SDD shows how to structure a software system to encounter the demands. It is the main reference for code development and, consequently, it must carry all the data needed to write code.

4. RESULT AND ANALYSIS

In this section, performance of the existing algorithms under various parameter settings via simulations is presented. The MATLAB is used to carry out the performance study of VELCT with respect to existing topology. A WSN system comprising of 50 nodes was used in the simulation scenario. figure 2 shows performance of VELCT with existing topology and transmitting more number of packets in VELCT.

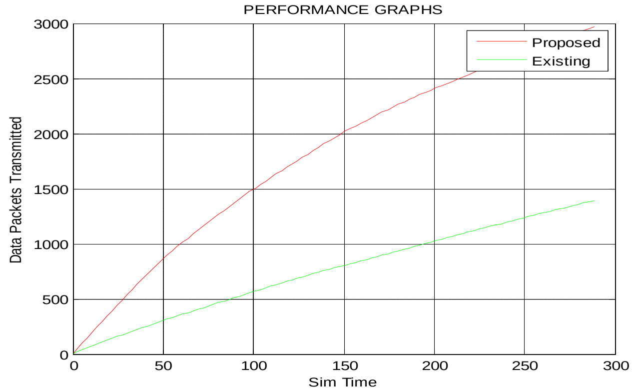

Figure 2: Packet transmitted versus time.

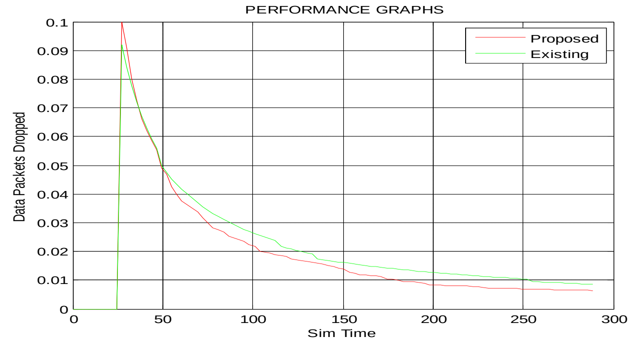

Figure 3: data pocket dropped versus time

Figure 3 shows a dropped data pockets versus time. As in the figure the packet dropping ratio is reduced in VELCT when compared to existing topology.

Figure 4 shows the performance of VELCT in terms bandwidth utilization ratio with respect to time. Observing that the bandwidth utilization is decreased when compared to the existing system.

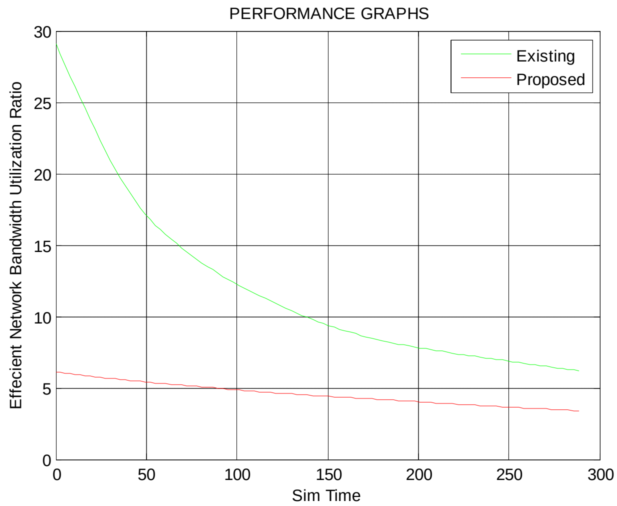

Figure 4: bandwidth utilization ratio versus time

5. CONCLUSION

On considering the raising the impact of WSNs on real time civil and military applications, more number of sensor nodes are required to monitor the large-scale areas. In this paper, VELCT (Velocity Energy-efficient and Link-aware Cluster-Tree) is a proficient method is proposed to construct a mobility-based auspicious network management architecture for WSNs, to exploit the network lifetime, connection time, residual energy, RSSI, throughput, PDR and stable link for mobile sensor nodes, whereas each cluster member chooses the cluster head with better connection time and forwards the data packets to the corresponding cluster head in an allocated time slot. Similarly, the sink or DCN elects the one-hop neighbour DCN or cluster head with maximum threshold value, connection time, RSSI and with less network traffic. From the simulation results, it is revealed that VELCT provides more stable links, better throughput, energy utilization and PDR with reduced network traffic than existing protocols.

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