Collision Optimized Broadcast Scheduling in Wireless Sensor Network

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ABSTRACT
Broadcasting plays an important role in the communication protocol design and it acts as a fundamental operation in wireless sensor network (WSN). This paper investigates the Minimum Latency Broadcast Scheduling in Duty Cycled (MLBSDC) problem in WSN. The MLBSDC problem aims to find a broadcast scheduling that minimizes the time in which the last node receives the broadcast message with minimum collision. The focus is mainly on providing minimum collision and finding the lower bound of broadcast latency. In this paper, a novel algorithm Collision Optimized Broadcast Scheduling (COBS) is proposed which is a refinement of Effective Broadcast Scheduling with Optimized Latency (EBSOL) [9] algorithm. COBS allow nodes in different layers of the broadcast tree to transmit the message simultaneously. In EBSOL, the latency is efficiently reduced by layer by layer approach and the broadcast tree is constructed. It is proved that COBS produces a latency of at most 12 |T|, where T denotes the number of time slots in a scheduling period. To prevent collision, each node maintains an effective routing table and only one parent node transmits the message to the child node. The results from extensive simulation show that COBS has a better performance than the existing One To All Broadcast (OTAB) algorithm in terms of reduction in latency, number of transmission and collision.

Keywords: Broadcasting, wireless sensor network, duty cycled environment, latency, scheduling

1. INTRODUCTION
Wireless sensor network consists of numerous sensor nodes deployed in the field. These nodes are usually resource constrained in terms of battery lifetime and computation, and they are equipped with a number of sensing elements. They communicate each other with one or more radios via multi-hop communication. There exist one or more sinks to collect sensed data and to issue commands that affect the operation of sensor nodes. Sensor nodes are generally battery-powered and operate in environments where replacement of battery is not feasible. Meanwhile, many applications of WSNs need to last for a long duration. A well-known approach to save energy is the Duty-Cycled method [10]. In a Duty Cycled environment, the nodes will be in active state for a short span of time and all the transactions will happen only in that active state. A sensor node in duty cycled environment alternate its mode between sleeping and active state to conserve energy. However, the intermittent connections of a duty-cycled network make the Minimum Latency Broadcast Scheduling (MLBS) [2] problem different from conventional cases. In particular, a sensor node needs to transmit a message multiple times to its neighbor nodes at different active time slots. The multiple transmissions result in a longer broadcast latency and more energy consumption. The focus is mainly on reducing collision and latency in broadcast scheduling. The existing algorithm for Minimum Latency Broadcast Scheduling Duty Cycled in wireless network [5] is One To All Broadcast (OTAB) algorithm which has an approximation ratio of 17|T|, where |T| denotes the number of time slots in a transmission. In this paper, for Duty Cycled environment the COBS algorithm is used. COBS allow the nodes to broadcast scheduling in Uncoordinated Duty Cycled wireless sensor networks, and it produces a approximation ratio of at most 12|T|. The main challenge in WSN application is the time taken to transmit the message from a source node to the destination node. Collisions can be detected by identifying the common neighbors of two or more transmitting nodes via topological information and ensuring that the interfering nodes transmit in different time slots.

2. RELATED WORK
Several approximation algorithms were proposed by different authors for effective broadcast scheduling in wireless sensor network. Y.Duan et.al. [1] provided a generalized framework to solve the MLBSDC problem. The broadcast scheduling is considered under the protocol interference model, in which each node s_i is associated with two radii: the transmission radius r_{Ti} and the interference radius r_{Ii} . W Ye et.al. [2] presents a sensor-MAC (S-MAC), a new MAC protocol explicitly designed for wireless sensor networks. The protocol has a good scalability and collision avoidance capability. R. Mahjourian et.al. [3] proposed an approximation algorithm Conflict-Aware Broadcast Scheduler (CABS), which is guaranteed to generate a broadcast schedule whose latency is within a constant ratio of the optimal solution. It uses a layer-by-layer technique to compute the broadcast schedule. D Bozdag et.al. [4] presented an efficient parallel distance-2 coloring algorithm suitable for distributed memory computers and experimentally demonstrated its scalability. The main idea of parallel distance-2 coloring algorithm is to color boundary vertices concurrently in a speculative manner and then detect and

rectify conflicts. Stojmenovic et.al. [5] proposed a broadcasting algorithm to significantly reduce or eliminate the communication overhead of a broadcasting task by applying the concept of localized dominating set. C Hua et.al. [6] discussed about a different asynchronous random sleeping (ARS) mechanism for sensor networks, whereby sensors wake up randomly and independent of others in each time slot. B. Tang et.al. [7] establishes a lower bound on message complexity of any distributed algorithm for nontrivial CDS. The three known distributed approximation algorithms for MCDS are Das algorithm, Wu and Li's algorithm, Stojmenovic algorithm is reinvestigated. PJ Wan et.al. [8] proposed an approximation algorithm for Connected Dominating Set (CDS) that consists of two phases, which construct a maximal independent set (MIS) and a dominating tree, respectively. A.Fathima Ramzi et.al [9] describes the EBSOL algorithm which minimizes the latency by layer by layer approach by constructing the broadcast tree.

3. THE COLLISION OPTIMIZED BROADCAST SCHEDULING ALGORITHM

The Wireless Sensor Network (WSN) relies strongly on broadcasting such as information dissemination, route discovery and code update. The three main phases of the COBS algorithm are inner layer broadcast algorithm stage, CDS construction and CDS ranking and scheduling. At the initial stage, the layer by layer transmission process is done by using Inner Layer Broadcast Scheduling (ILBS) algorithm. The nodes are grouped into layers based on the latency between the source node and the other nodes. Transmission is done in layer by layer and the Maximal Independent Set (MIS) is formed for every layer. To avoid this collision Distance 2 (D2) coloring method is used. D2 coloring method is used to assign color to every node to reduce the collision. Nodes with the same color will be transmitted at the same time to avoid collision. Two parent nodes of a node should not share the same color to avoid collision. Connected Dominating Set (CDS) is the set of nodes which has the dominating character to transmit the message to the child nodes. For each layer the CDS is constructed. The parent node transmits the information to these dominating node and these nodes will transmit to the other nodes in the layer. Ranking and broadcast scheduling of the nodes are done based on the two sets, MIS and CDS.

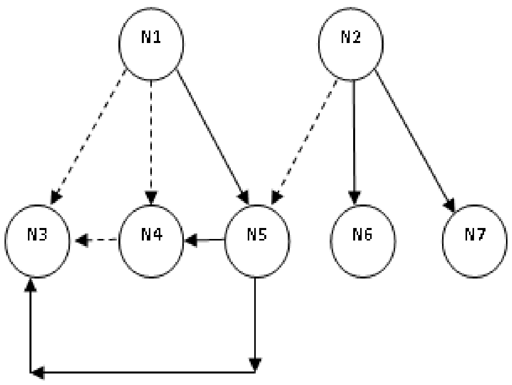

Figure 3.1 Connected Dominating Set (CDS)

Here node N5 is referred as the Dominating node which is connected to N3 and N4. So here the CDS will have the node N5 as shown in figure 3.1.

3.1 ILBS - Inner Layer Broadcast Scheduling

The broadcast scheduling between two disjoint set of nodes in the same layer was done by using Inner Layer Broadcast Scheduling (ILBS). Nodes are grouped into Parent-Nodes set and Child-Nodes set where every node in the Child-Nodes set is adjacent to at least one of the nodes in the Parent-Nodes set. Then the MIS (Maximum Independent Set) is constructed. The MIS process reduces the number of transmission from one node to another within the same layer and the nodes are partitioned into different subsets according to their active time-slots. At each layer L_k, the maximal independent set A_j of L_k, which is also independent of the previously constructed maximal independent sets in A_{j-1}.

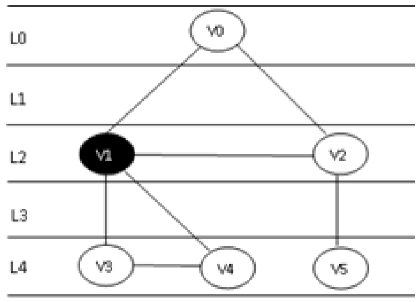

Figure 3.2 MIS selection in ILBS

Once the maximal independent sets have been found, the broadcast tree is constructed. The MIS process reduces the number of transmission from one node to the other node in the same layer.

In Figure 3.2 [9], the nodes are arranged in different layers. Maximal Independent Set indicates a Solid Circle and the hollow circle indicates a non-independent nodes. Here V0 is the source node which selects v1 as a MIS based on the total number of available child nodes.v1 will retrieves the message from v0 and then it transmits the message to v3, v4 as well as v2.

3.2 Distance 2 Coloring Method

A Distance 2 (D2) coloring method is the process of assigning colors to every node to reduce the collision. Assigning of color is done in two methods, first method is front to back ordering and second method is smallest degree last ordering. In Front-To-Back ordering, the coloring proceeds from the first node to the last node. In Smallest-Degree-Last ordering, two parent nodes must not share the same color if a child node can be traversed from both the parent nodes. Based on the latency, different colors are assigned to the nodes in the same layer.

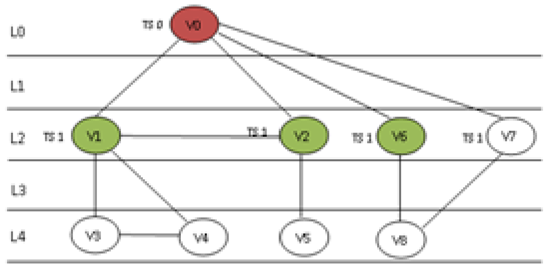

Figure 3.3 D2 Coloring Method.

In D2 coloring, the main process is coloring the nodes to prioritize the transmitting node. Nodes with the same color will be transmitted at the same time to avoid collision as shown in Figure 3.3 [9]. D2-coloring is a feasible method to prevent collision of a broadcast in multi-hop wireless networks, where nodes with a same color can transmit at the same time slot without collision. In the Figure 3.3, v1, v2 and v6 are marked with same color and start the transmission at the same time.

3.3 Connected Dominating Set (CDS) construction

Connected Dominating Set (CDS) is the set of nodes which has the dominating character to transmit the message to the child nodes. For each layer the CDS is constructed. The parent node transmits the information to these dominating node and these nodes will transmit to the other nodes in the layer. In COBS, Construct the shortest path tree via Dijkstra's algorithm. Then, it constructs the MIS to form a backbone by considering one layer at a time starting from layer 0 to the leaf layer.

In particular, source node s will be the first node to be added into CDS, and no node in layer 1 of shortest path tree will be selected because they must be adjacent to source node. The process then continues for layer 2 and so on, whereby nodes at each layer which are not adjacent to those in CDS are selected.

The Procedural steps for Collision Optimized Broadcast Scheduling; A Sample network of 20 nodes is taken for illustration in Figure 3.4.

Step 1: Deriving the CDS.

Step 2: The main process of COBS algorithm is to find MIS and to compute the CDS. Finally ranking & scheduling is performed based on CDS.

Step 3: MIS is done based on layer by layer process, in this example the MIS would be derived for the layers L0, L1, L2, L3, L4 and L5.

Step 4: The MIS value for L0 is source node's', L1 is node V2 and so on for the other layers

Step 5: The final derived MIS value as a set {s, v2, v6, v12, v16}.

Step 6: Next process is to derive the CDS. Every node in the network is examined with the set of CDS nodes. Select the nodes only if there is no direct traverse between the node and the CDS set.

Step 7: By default the source node's' is selected as CDS.

Step 8: The selection of nodes to examine the CDS is done layer by layer.

Step 9: MIS of the Layer L1 is selected to examine the CDS which results, the node v2 is selected for the process.

Step 10: As there is a direct traverse between the node s and v2, the node v2 is not selected for CDS.

Step 11: Similarly all the remaining nodes in layer L1 were examined and none would be selected because all the nodes have a direct traverse from node's'.

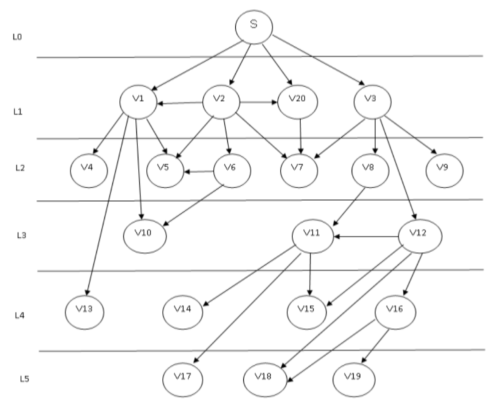

Figure 3.4 CDS Construction reference network

Step 12: In layer L2, first select the MIS node i.e. node v6 is to examine with CDS.

Step 13: As there is no direct traverse between the node s and v6, the node v6 is selected for CDS.

Step 14: In the same way other nodes in the layer L2 is examine with the CDS set and included the nodes v4, v7, v8 and v9 in the CDS.

Step 15: Finally in layer L2, the CDS set contains the following nodes {s, v6, v4, v7, v8 and v9}.

Step 16: This process is continued for the entire layer.

Step 17: The final CDS set contains the following nodes {s, v6, v4, v7, v8, v9, v12, v13, v14, v17 and v19}.

Step 18: At last, ranking and scheduling the nodes based on CDS is done for transmission.

Step 19: The ranking is done layer by layer and highest rank is given for the MIS then the CDS set and then the remaining nodes in the layer.

Step 20: The final ranking is given as {s, v2, v1, v20, v3, v6, v4, v7, v8, v9, v5, v12, v10, v11, v16, v13, v14, v15, v17, v19 and v18}.

3.4 Ranking and Scheduling the transmission based on CDS

COBS use the ranking process to construct the broadcast tree, whereby nodes with the greatest rank will be scheduled to transmit first. The ranking would be done based on the CDS and MIS. Nodes in CDS will be provided with the higher rank and then the MIS nodes are ranked. At last the other nodes are ranked. Broadcast scheduling performs based on the above ranking process. The higher rank node will be scheduled first and the lowest rank is scheduled last.

4. EXPERIMENTAL EVALUATION

In this section, the performance of the Collision Optimized Broadcast Scheduling (COBS) algorithm is analyzed. The broadcast latency and the total numbers of transmission are evaluated by using extensive simulations. NS2 simulator is used for the network simulation. The broadcast latency is the total time slots required by all the nodes to receive the broadcasted messages. The performance of the COBS is compared with that of the OTAB algorithm. All the nodes are randomly deployed in a sensing area of 930m*500m. Network latency is defined as the time delay observed as the data transmits from one point to another. It is the total time taken for a message to transmit from one node to its destination node.

In a wireless sensor network, Latency increases when the number of nodes gets increased. After some 200 nodes the increase of latency is gradual. With a denser network, a forwarding node potentially needs to wait longer to transmit its message to avoid a collision. The latency is always getting increased as the number of nodes or the density of the network increases. Figure 4.1 shows that the latency of the COBS algorithm is much lesser than the OTAB algorithm, in which the number of nodes is plotted in x-axis and the broadcast latency, is plotted in the y-axis.

Figure 4.1 The effect of varying the number of nodes on broadcast latency for COBS and OTAB

A collision is the result when two nodes in the network attempting to transmit a data at exactly the same time to a particular node. Collision increases due to number of transmission increases. When the number of transmissions increased the option to reach the node also gets increased, the reason for the retransmission of data happens due to collision. Collision and the number of transmission are directly proportional to each other. Also the number of transmission will get increase when the number of nodes increased.

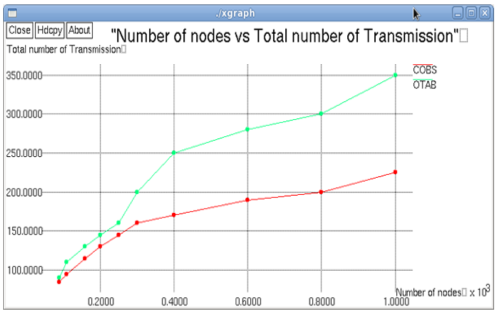

Figure 4.2. The effect of varying the number of nodes on number of transmissions for COBS and OTAB

Whenever there is an increase in number of nodes, the size of the broadcast tree and the number of child node also gets increased and so the number of transmission will also get increased as shown in the Figure 4.2.

Only one energy source will exist on a nodes live position, that representing the total energy and it reserves that energy for sensing, transmitting and receiving of messages. In a network there are multiple numbers of nodes and every node have some energy and it becomes monitored by the models by use of COBS technique, representing different devices. The energy is calculated based on the following formula:

$$\text{Energy} = \text{Power} * \text{time} \qquad \text{------>} \; (4.1)$$

The equation 4.1 is a formula for identifying the energy. When the number of nodes in the network increases, the number of transmission will also gets increased and which makes the usage of energy will also increases. The increase in the number of nodes increases the interaction between the nodes and so the energy consumption of each sensor node is getting increased. According to the Figure 4.3, the number of nodes plotted in x axis and the energy plotted in y axis. COBS algorithm has high energy efficiency and the work time is high when comparing to OTAB.

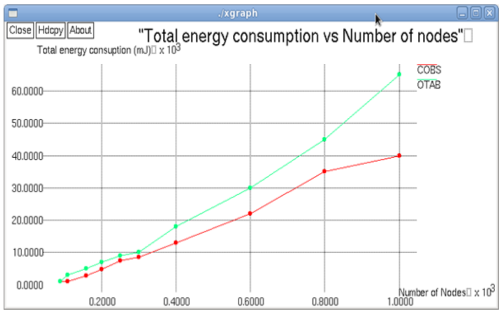

Figure 4.3 The effect of varying the number of nodes on energy consumption for COBS and OTAB

The energy is always a limited source for any sensor network and the energy source recharging will not happen frequently. So the life time of the sensor node is much depends on the energy utilization of the available energy.

The performance metrics latency, energy and the number of transmission always have impact based on the total number of working period.

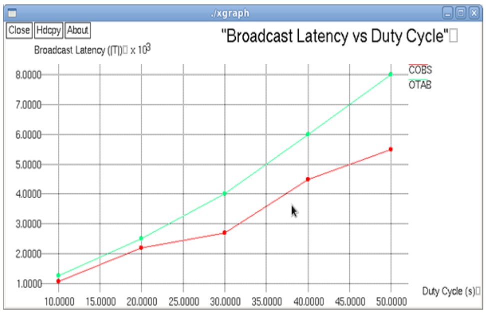

Figure 4.4 The effect of varying length of the duty cycle on broadcast latency for COBS and OTAB

When the total working period increases, the number of messages will also gets increased. Figure 4.4 shows the impact of latency because of increased length of the working period. The analysis is done with a low density environment of 200 nodes with some varying working periods. The broadcast latency of all the nodes will increase because the working period has more time slots, the number of layers on the shortest path tree increases, resulting in the higher latency of the broadcast schedules. The analysis result of the impact of latency with respect to the working period is shown in the Figure 4.4.

The latency is increased with the increase in the length of working period. While comparing the OTAB algorithm, COBS has a better latency with respect to different working period or duty cycle. The total number of transmissions grows with the increase of the duty-cycle. This is because each forwarding node may require more transmissions to inform all of its neighbor nodes with different active time slots.

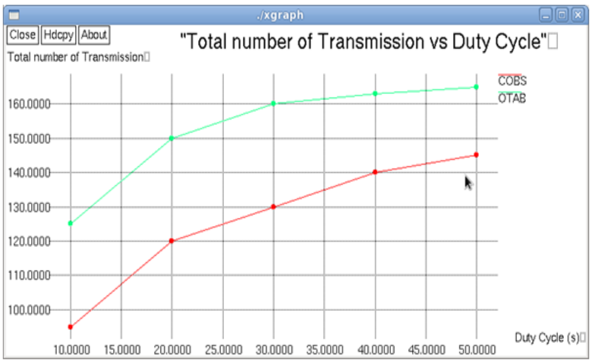

Figure 4.5 The effect of varying the length the duty cycle on number of transmissions for COBS and OTAB

The analysis result of impact of transmission because of the difference in the number of working period. In the Figure 4.5 the total length of the working period is plotted in x-axis and the number of transmission is plotted in the y-axis. Since each forwarding node may require more transmissions to inform all of its neighbor nodes with different active time slots the number of message transmission will also get increased. COBS algorithm is having less number of transmission than OTAB algorithm.

5. CONCLUSION AND FUTURE WORK

The COBS algorithm is proposed to improve the performance of the MLBSDC problem. The latency time for a node to transmit a message from source to the destination is reduced in the COBS algorithm. The number of transmission is reduced using the COBS algorithm which yields less collision and the energy utilization is also optimized. The simulation results indicate that COBS has a better performance, in terms of the broadcast latency, collision and number of transmission, than OTAB under different network configurations.

The current implementation of COBS algorithm is done in a distributed manner. The use of COBS method under the physical interference model is another possible future work. Under this model, we need to consider both collisions and total interference from nearby transmitters.

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