ISSN 2278 – 3091

International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE), Vol. 4 , No.4 Pages : 06 - 09 (2015)
Special Issue of ICEEC 2015 - Held on August 24, 2015 in The Dunes, Cochin, India
http://warse.org/IJATCSE/static/pdf/Issue/iceec2015sp02.pdf

Duty-Cycle-Aware Minimum Latency Broadcast Scheduling in Clustered Multi-hop Wireless Networks

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Abstract : Broadcast is an essential and widely-used operation in multi-hop wireless networks. Minimum latency broadcast scheduling (MLBS) aims to provide a collision-free scheduling for broadcast in multi hop network . Previous work mostly assumes that nodes are always active, and thus are not suitable for duty-cycle-aware scenarios. Here investigate the duty-cycle-aware minimum latency broadcast scheduling (DCA-MLBS) problem in clustered multi-hop wireless networks . Prove both the one-to-all and the all-to-all DCA-MLBS problems to be NPhard. The approximation algorithms called OTA for the one-to-all DCA-MLBS problem, and ATA for all-to-all DCA-MLBS problem under the unit-size message model respectively are used for scheduling. Here we investigate the broadcast scheduling in clustered Multihop wireless network and identified the scheduling time. As compared to existing works, in clustered scenario the scheduling time get reduced especially in clustered ATAM algorithm

Keywords : Cluster, Duty cycle, Multihop network, Scheduling.

INTRODUCTION

Multihop wireless networks consist of nodes with a limited transmission range. Broadcast is one of the most essential operations in multihop wireless networks, and is widely used for routing discovery, data collection, code update, etc[1]. The two most commonly used broadcast tasks are the one-to-all broadcast and the all-to-all broadcast (also called gossiping). The one-to-all broadcast aims to disseminate a message from one source node to all the other nodes, while the all-to-all broadcast aims to distribute the messages from all the nodes to all the other nodes. In multihop wireless networks, although the packets transmitted by a node can be received by all the nodes within its communication range, two parallel transmissions to one common node can cause signal collision, and the common node will receive neither of the two messages. Minimum latency broadcast scheduling (MLBS) aims to minimize the broadcast latency while ensuring that the transmissions are collision-free. The MLBS problem in multihop wireless networks has been proved to be NPhard[1].

The MLBS in clustered Multihop network aims to reduce the scheduling time. The scheduling time is the transmitting time slot of a node in its active time slot. Unlike in conventional scenarios without sleep cycles, a node in duty-cycled scenarios with active/sleep cycles may require transmitting several times to inform all its neighboring nodes with different active time[27]. Therefore, most of the previously proposed broadcast scheduling algorithms are not suitable for duty-cycled scenarios. Unit size message model is used in the one to all(OTA) broadcast algorithm and all to all(ATA) broadcast algorithm. The approximation ratios of algorithms are then computed using unit size message model. The main problems that can be faced during scheduling is the collision, it can be reduced by coloring of parent nodes.

Instead of finding transmitting time slot of entire network, here divide the network into several clusters .Then apply the approximation algorithms. In the case of clustered One TO All Modified (OTAM)broadcast scheduling ,the transmitting time slot of nodes are sometimes greater than that of existing system. But in a clustered All To All Modified(ATAM)broadcast scheduling, the transmitting time is always less than that of entire network. Even though the network is divided into clusters the maximum value of transmitting time is considered and always less in ATAM.

RELATED WORK

There have been several studies done in broadcast scheduling problem in Multihop networks. The first and simplest implementation was flooding [17], which may cause large amount of collision. Usually Multihop network has model as unit disk graph (UDG) ,if the nodes are in same transmission radius. Lots of algorithms have been presented for MLBS problem. Gandhi et al. [2] introduced an approximation algorithm with a constant ratio of more than 400. Huang et al. [3], improved ratio to 16 and is recently improved to 12 by Gandhi et al. [4], where the interference radius is α times as large as the transmission radius. The broadcasting problem has been presented in[7][14]. Energy saving methods in broadcasting has been implemented in [13][16].

The works has been done for all-to-all MLBS problem are, first by Gandhi et al. They presented first collision free broadcast scheduling algorithm with constant approximation ratio of more than 1000. Huang et al. improved this to 27 and again Gandhi et al. improved the ratio to 20.The same problems are studied under unbounded message model by [8], [9].The broadcast scheduling problem in duty cycled scenario has done in [10] and [11]. Hong et al. presented an algorithm named ELAC. Earlier studies didn’t consider the active/sleep state of nodes. But ELAC has considered this active and sleep state of nodes and explained the algorithm using maximal independent set (MIS)[18] and D2 coloring[19]. The D2 coloring uses special geometric behavior of MIS and reduced collision.

However in ELAC it requires two times of colors for transmission between two layers. This will lead to broadcast latency. Other than broadcast scheduling, link scheduling has been introduced in[24][25][26] and aggregation scheduling in[21][22]. The data gathering

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algorithms are explained in[23] and interference aware broadcasting presented by Jiao et all in[5], and interference minimization has been discussed in[12].

PRELIMINARIES

Network Model

Model the multihop wireless network as a UDG $G = (V, E)$, where V contains all the nodes in the network, and E is the set of edges, which exist between any two nodes if their Euclidean distance is no larger than the transmission radius[15][20]. A node cannot send or receive the message at the same time. Assume that nodes determine the active/sleep time without coordination in advance, and thus do not require additional communication overhead. The duty cycle is defined as the ratio of the active time to the whole scheduling time. The scheduling time is divided into multiple scheduling periods of the same length. One scheduling period T is further divided into unchanged $|T|$ unit time slots, i.e., $|T|$ = { 0,1,2,…….. $|T|$-1} .Every node v chooses one active time slot $A(v)$ in T randomly and independently, and wakes up at this time slot in every scheduling period to receive the message. If node v wants to send a message as required, it can wake up at any time slot to transmit the message as long as the receiver node is awake and there is no collision for this transmission[1]. A node can transmit the message at any time-slot, but is only allowed to receive the message at its active time-slot. If we choose node *s* as the source node, for every edge(u, v) $\in$ E, the latency $Lat(u,v)$ of this edge is determined as follows:

$$\text{Lat(u,v)}=\begin{cases} A(v)+1 & u=s \\ A(v)-A(u) & if A(v)-A(u)>0 \\ A(v)-A(u)+|T| & else \end{cases} \quad (1)$$

Problem Formulation

This paper studies the one-to-all and the all-to-all broadcast problems in clustered Multihop networks. In the one-to-all broadcast problem, one distinguished node disseminates its message to all the other nodes[1]. The one-to-all broadcast completes when every node receives the message. In the all-to-all broadcast problem, every node has a message to send to all the other nodes. The broadcast task completes when every node receives the messages from all the other nodes .Model the broadcast scheduling as assigning the transmitting time slots for all the nodes, i.e., assigning a function TTS : $V \rightarrow 2^N$,where N denotes the natural number set. The objective of broadcast scheduling is to minimize the largest transmitting time slot[1]. Furthermore, the broadcast scheduling in duty-cycled scenarios requires taking the following two constraints into account. First, a transmitter node can transmit messages to a receiver node only when the receiver node is awake. Second, the transmissions should be carefully scheduled to avoid the collision[1].

BROADCAST SCHEDULING ALGORITHMS

Clustered One To All Modified (OTAM) Algorithm

Algorithm 1
Input: G = (V, E, A.)
Output Gossiping Scheduling TTS : $V \rightarrow 2^N$

1. Divide the entire network into different clusters
2. Constructs a shortest path tree T_{SPT} by applying Dijkstra's algorithm, rooted at source node s maximum latency of the shortest path tree T_{SPT} rooted at this node is the minimum. Latency should be obtained from Lat(u,v) to all the nodes.
3. Divide all the nodes into different layers L_0, L_1, L_2,,,,, L_D according to the latency of the shortest paths from node s to all the nodes in T_{SPT}.
4. Construct the MIS'es(Maximal Independent Set) and the broadcast tree, and color the parent nodes
5. Schedule the transmissions from the parent nodes to their children nodes based on the colors of the parent nodes. This scheduling starts at time slot 0, and works layer by layer.

OTA algorithm in clustered Multihop network working starts from dividing the network into different clusters. The nodes are assigned with different active time slots. Then construct shortest path tree T_{SPT} by applying Dijkstra's algorithm in each cluster. The edge weight of the network should be the maximum latency from source node to the particular node. The latency should be obtained from Lat(u,v) to all nodes. Based on the latency from source node, nodes in T_{SPT} are divided into different layers L_0, L_1, L_2…… L_D . The layering operation is used to construct the broadcast tree and schedule the broadcast[1]. For constructing Maximum Independent Set(MIS) first of all construct a set U_i in each layer based on the active time slot ,ie MIS is constructed layer by layer. From that set find out the MIS and grouped into another set Q_j. Then find out the independent set(IS) , all the nodes in each layer are divided into two subsets, IS M_i and L_i/M_i [1].

The broadcast tree T_b is constructed layer by layer. At each L_i, parent nodes of nodes in M_i are chosen from some nodes at higher layers. Some nodes in M_i are chosen as the parent nodes of nodes in L_i/M_i and nodes at lower layers at same time slot[1].

Next step is the coloring of nodes to reduce the collision during scheduling. A proper Distance 2 coloring (D2 coloring)of G is the assignment of colors labeled by natural numbers to the nodes in V[6]. Here D2 coloring with front-to- back ordering and smallest degree last ordering is used, the colors are assigned to parent nodes.

Finally scheduling process starts, based on broadcast tree and coloring of parent node. The scheduling proceeds layer by layer. Non-independent nodes are considered as an accelerating node, which selected as a parent node for some independent nodes in the next layer. Initially, only the source node s is ready to transmit a message. From a starting working time slot t, the algorithm iteratively schedules transmissions to cover all nodes in each layer. Non-independent nodes are selected as a parent node for some independent nodes in the next layer[6].

Clustered All-to-All Modified (ATAM) Algorithm

Clustered ATAM has two phases. In the first phase, all the messages are gathered to one special node. Then these messages are broadcasted from this special node to all the other nodes.

Algorithm 2
Input: G = (V, E, A).

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Output: Broadcast Scheduling TTS : $V \rightarrow 2^N$

1. Divide the entire network into different clusters
2. Find a special node s such that maximum latency of the shortest path tree T_{SPT} rooted at this node is minimum.
3. Assign maximum latency(T_{SPT}) to D, and divide V into $L_0, L_1, L_2,,,,, L_D$
4. Construct the MIS'es(Maximal Independent Set) and the broadcast tree, and color the parent nodes
5. Invoke algorithm 3 to gather the messages to node s.
6. Node s sends the message to all other nodes at time slot t, t is the time slot when the data gathering completes.
7. Schedule the transmissions from the parent nodes to their children nodes based on the colors of the parent nodes. This scheduling starts at time slot 0, and works layer by layer.

Algorithm 3

1. Construct BFS tree T_{BFS} routed at special node s.
2. Assign a maximum value of depth as d and divide V into depth layers $S_0, S_1, S_2,,,,, S_d$.
3. Set interval depth as three and find a node u such that one of its neighboring node v has a message to transmit or forward.
4. Schedule the transmission and increment time t until all the nodes transmit the message.

In contrast to one to all broadcasting, all to all broadcast algorithm select a special node and collect all messages. Then schedule the transmission similar in one to all broadcast.

RESULT AND PERFORMANCE EVALUATION

In this section ,we evaluate the performance of the broadcasting algorithms in clustered Multihop network. The implementation of algorithms done using java and extensive simulations are done in one simulator. The performance of OTAM and ATAM algorithms in clustered network are compared with algorithms in conventional entire network.
All the nodes are randomly deployed in 200mx200m rectangular area . Then we study the effect of different network configurations especially network size and duty cycle.

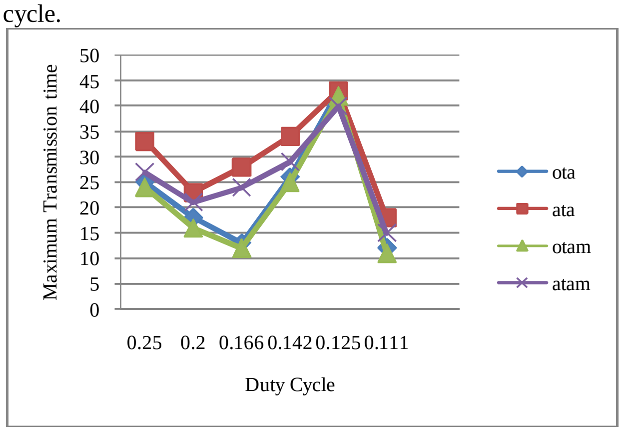

Fig1: maximum duty cycle against maximum transmission time

X axis : duty cycle
Y axis : maximum transmission time

Table 1: Duty cycle and Transmission time of Fig 1

Duty cycle	Maximum Transmission Time			
	OTAM	OTA	ATAM	ATA
0.25	24	25	27	33
0.2	16	18	21	23
0.166	12	13	24	28
0.142	11	12	15	33
0.125	42	43	40	43
0.111	11	12	15	18

Here maximum duty cycle is in x axis and maximum transmission time is in y axis. First , maximum duty cycle is set as 9. From Fig 1 it is clear that in the case of OTAM(OTA in clustered network) sometimes the transmitting time is close to that of conventional OTA.. But in ATA clustered network ATAM(ATA in clustered network) shows better performance that is, transmission time reduced. Table 1 shows the maximum transmission time in different duty cycles.

CONCLUSION

This paper studies the MLBS problem in clustered Multihop wireless network. The existing OneToAll and AllToAll broadcast scheduling algorithms are modified for clustered network thereby found out variations in transmitting time slot. In the case of clustered OTAM broadcast scheduling sometimes the time fluctuate. ie transmitting time is varying in nature. But in clustered ATAM broadcast scheduling transmitting time is reduced much as compared to entire network.

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ISSN 2278 – 3091

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