

# On the Construction of a Collision-Free Schedule of Beacons in a Wireless Multi-Hop Network

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**Abstract**—Organizing multi-hop wireless networks medium access control is a challenge due to the presence of the hidden node problem. It requires reliable coordination among neighbours and second-hop neighbours. In this paper we propose the construction of a collision-free beacon schedule that can be a first step towards the orchestration of effective medium access. The construction process involves iterative trial and error until a collision-free schedule is found. The participating nodes will keep changing the schedule until all the beacons are successfully received. At this point, the nodes simply keep repeating the successful schedule.

**Index Terms**—Medium Access Control, decentralized constraint satisfaction solver, learning MAC protocol

## I. INTRODUCTION

MEDIUM access in multi-hop wireless mesh networks is complicated by the fact that not all the stations are in each other's transmissions range. Therefore is no longer possible to rely on Carrier Sense Multiple Access to coordinate the access to the medium. It is likely that transmissions overlap and interfere with each other. A completely random MAC protocol will not offer satisfactory performance. Some kind of coordination among neighboring nodes is needed.

## II. IEEE 802.11S MESH BEACON COLLISION AVOIDANCE

A Mesh Beacon Collision Avoidance (MBCA) is described in [1]. The solution consists of sometimes delaying the beacon transmission to check for possible overlapping transmissions among the one-hop neighbours. It also involves including information about the timing of beacons in beacons.

This approach has some shortcomings. It does not prevent that two-hop neighbors choose overlapping beacon transmitting instants. The timing information in beacons is available only in case of successful transmission and reception. In the critical case in which collisions occurs and timing information is needed, it is not available. Delaying the beacon sometimes seems also problematic. It is not impossible that the two colliding beacons choose to delay simultaneously and therefore the collision is not detected. If the beacons are not delayed very frequently, it takes a long time to detect the collision. If the beacons are delayed frequently, additional randomness is introduced that can easily result in more collisions.

## III. ASSUMPTIONS

We model the network topology as a graph. In the topology graph, the nodes represent wireless stations and the arcs between two nodes mean that those nodes can communicate with each other. If a node has two neighbours transmitting simultaneously, it is assume that the messages are garbled and lost. A node can only detect and receive the transmissions of its immediate neighbours, and only if there is a single neighbour active.

In reality, wireless propagation is much more complicated. The carrier sense range exceeds the transmission range and there is capture effect. There are a large number of factors that determine whether a transmission is successful or not. Nevertheless, for tractability, we use the above described graph model.

## IV. A BEACON SCHEDULE

A recurrent solution in wireless networks is the use of beacons for synchronization and signaling. Beacon messages are very short, which means that the likelihood of collisions is lower. This beacons can be very useful for network coordination and management.

A schedule of beacons defines special times in which beacons can be transmitted. Let us assume that beacons should be transmitted every  $T_b$  seconds. Then, it is also necessary to define a schedule length  $S$  which is the number of beacons in a schedule. Each station transmits a beacon once in every schedule in one of the  $S$  allowed time instants. When the schedule is over, it is repeated again.

A beacon includes a list of all the beacons received by the station in the last schedule. When a station  $A$  receives beacons from all its neighbors confirming that they have received the beacon of station  $A$ , this station can assume that its beacon has not suffered any collision.

The challenge is to construct a schedule in such a way that all the neighbors of a station can listen to its beacon. When such schedule is successfully constructed, all the nodes will receive confirmation of successful reception of its beacon from all neighboring stations.

## V. THE INTERFERENCE GRAPH

From the topology graph we derive the interference graph. There is an arc between two nodes the simultaneous transmission of those two nodes results in interference. Given the interference graph, the problem reduces to map coloring problem.

We are interested in solving this problem in a decentralized way, as there is no central entity that has the global view of the network and can magically configure all the nodes. Only *after* the problem has been solved, the network will work and the administrator will be able to collect topology data and remotely configure the network.

Decentralized Constraint Satisfaction [1] is a promising alternative to address the problem. The constraints are that no pair of nodes connected by an arc in the interference graph should use the same color.

## VI. THE CONSTRUCTION OF A BEACON SCHEDULE

Each station picks a random position in the schedule. If it receives confirmation from all of its neighbors, it assumes that no collisions have occurred and keeps transmitting at that position. Otherwise

## VII. CONCLUSION

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