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NON-ORTHOGONAL MULTIPLE ACCESS FOR COLLISION AVOIDANCE IN LOW-POWER AND LOSSY NETWORKS

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ABSTRACT

Techniques are described herein for a Non-Orthogonal Multiple Access (NOMA) mechanism to improve network throughput due to multiplexing gain in the power domain. Several received Signal-to-Noise Ratio (SNR) levels may be set to achieve multiple access of nodes depending on different network requirements. In particular, these techniques may prevent hidden node collision by assigning different received SNR levels between the upward link and the downward link.

DETAILED DESCRIPTION

Channel hopping is a method of varying channels between transmissions in a pseudo random fashion in order to benefit from multiple channels in parallel and improve throughput. Channel hopping uses a pseudo-random sequence known to both transmitter and receiver. Compared with fixed frequency transmissions, channel hopping reduces the impact of loss on a particular channel due to an uncontrolled external interference or multipath fading on that particular channel.

The current Wi-SUN® standards use channel hopping to avoid collisions. The mechanism is efficient when few nodes transmit at the same time. However, it is not necessarily efficient enough for pure random/stochastic traffic. This is being recognized and the standards are now open to new strategies to reduce collisions and thus improve the efficiency of transmissions. Several collision cases may prevent a reception, including co-channel interference and hidden node collision.

Co-channel interference can still cause collisions likely due to an excessive number of transmissions to a single node at the same time, although unslotted Carrier-Sense Multiple Access with Collision Avoidance (CSMA/CA) and Clear Channel Assessment

(CCA) Mode 1 must be implemented, as described in Institute of Electrical and Electronics Engineers (IEEE) 802.15.4 sections 6.2.5.1 and 10.2.7, respectively.

In a hidden node collision, transmissions from the other side of the receiver interfere with the reception but were not detected by the sender in its listening process before the talk operation. This occurs because Wi-SUN randomizes the channel selection based on the destination Media Access Control (MAC) address only, so if a parent and a child of this node need to transmit a packet to this node at the same time, they will select the same channel, and may not be able to detect one another but still collide at the receiver.

Accordingly, a Non-Orthogonal Multiple Access (NOMA) mechanism is provided to avoid the aforementioned collisions in Low-power and Lossy Networks (LLNs). Briefly, the NOMA mechanism ensures that multiple nodes can transmit to the same destination node at the same time without collisions in LLNs.

According to the principle of NOMA, the received signal powers from multiple transmitters should be significantly different. This depends on the transmission power (Tx-power), transmission distance, and channel attenuation coefficient. Once the network infrastructure is deployed, it is too difficult to change the transmission distance and channel attenuation coefficient. Therefore, the Tx-power is the only option that can be designed to achieve different received signal powers.

Different Tx-powers may be set up for each channel at the transmitter, depending on the signal-to-noise ratio (SNR) of the received signal which is returned back from the receiver.

As illustrated in Figure 1 below, multiple nodes (e.g., node 1, node 2, and the hidden node) are connected to the destination node as child or parent nodes. The destination node may require these nodes to use various Tx-powers when sending a packet to it at the same time. This makes the huge difference among received signal powers and may enable de-multiplexing these received signals using a Successive Interference Cancellation (SIC) algorithm. Specifically, the configuration of the required Tx-power may use the PHYsical layer (PHY) Personal Area Network (PAN) Information Base (PIB) attribute phyTxPower and first depend on the received SNR of Destination-Oriented Directed Acyclic Graph (DODAG) Information Object (DIO) or Destination Advertisement Object (DAO) messages when the nodes are joining the DODAG network.

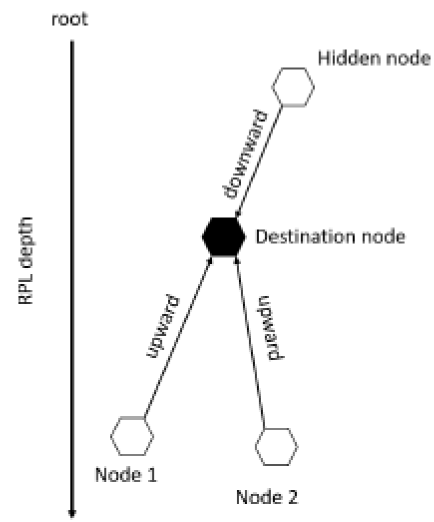

Figure 1

The limited levels of the required received SNRs may be designed depending on the system power consumption and the number of multiple access nodes.

In a Wi-SUN network, the destination node may be connected to many other nodes, and the level number of the required received SNR is equal to the maximum number of supported multiple access nodes. However, the limited levels of the required received SNRs may be established to prevent over-consumption of Tx-power. The typical number may be three, including high level, medium level, and low level. The destination node may require transmitters to adjust their Tx-power to achieve the well-setting level of the received SNR. In this case, each node may receive the messages simultaneously from up to three connected nodes. Therefore, a design scheme is presented for the assignment of the received SNR level, as shown in Figure 2 below.

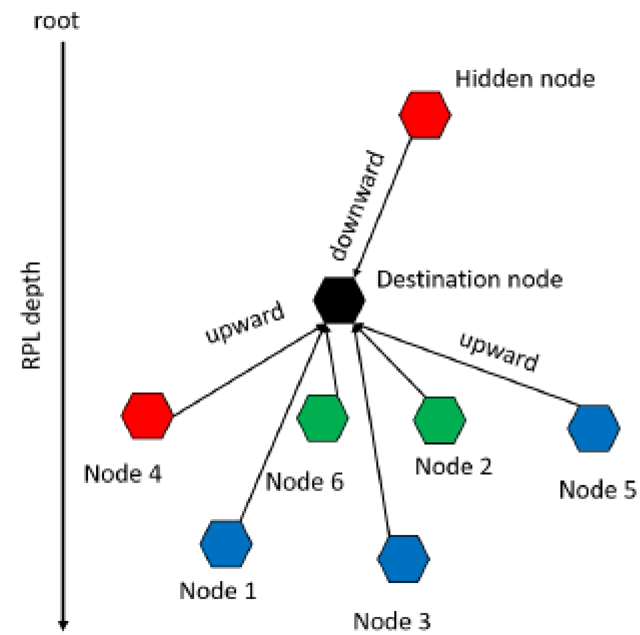

Figure 2

The green node is at the high level, the red node is at the medium level and the blue node is at the low level. The nodes belonging to different levels may transmit at the same time and may be de-multiplexed at the receiver using the NOMA mechanism described herein. The nodes belonging to the same level may transmit using the original CSMA-CA/CCA mechanism. This scheme supports partly multiplexed access nodes, which results in the improvement of the throughput of the network and the decrease of the collision.

The required SNR level may be dynamically assigned depending on the real-time Channel Status Information (CSI) and distance. Once the limited required SNR levels are determined, a dynamic assignment mechanism may be used to optimize the efficiency of multiple access.

Some rules may apply as follows. First, the longer the transmission distance, the lower the required SNR levels. If the long distance node is required for a high received SNR level, the Tx-power may become too large, resulting in low power efficiency, as shown in Figure 2 above. Second, the worse the CSI, the lower the required SNR level. The reasoning is similar to the first rule. Third, two nodes, which have a greater probability to transmit simultaneously, should be assigned to different levels. This may improve the multiplex access efficiency.

The destination node in Figure 2 above may dynamically assign the required SNR level of the connected nodes in the process through the PHY PIB attribute phyTxPower configuration.

The different received SNR levels may be designed for the upward link and downward link to solve the hidden node collision problem.

In DODAG networks, each node owns only one parent but many children. If a parent and a child need to transmit a packet to this node at the same time, they will select the same channel due to the channel selection based on the destination MAC address only in Wi-SUN, which results in a collision at the receiver. Applying the NOMA mechanism described herein and assigning the different received SNR levels for the parent node and child node may be utilized instead. The collision may be eliminated regardless of whether they are transmitting at the same time, as shown in Figure 3 below. The green node is at the high level, the red node is at the medium level, and the blue node is at the low level.

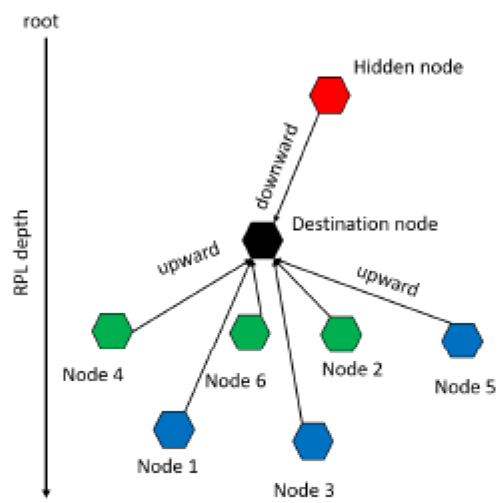

Figure 3

In summary, techniques are described herein for a NOMA mechanism to improve network throughput due to multiplexing gain in the power domain. Several received SNR levels may be set to achieve multiple access of nodes depending on different network requirements. In particular, these techniques may prevent hidden node collision by assigning different received SNR levels between the upward link and the downward link.