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ADAPTIVE TRANSMISSION POWER IN LOW-POWER AND LOSSY NETWORK

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ABSTRACT

Techniques are provided herein for intelligent transmission power control under different transmission patterns in a connected grid mesh. The transmission patterns include asynchronized transmission, broadcast transmission, and unicast transmission. They also provide a mechanism to help data packets compete against interference on specific channels and help high priority Quality of Service (QoS) packet have a greater chance to be received when congestion occurs. This enables the connected grid mesh to achieve higher reliability of communication with efficient power consumption.

DETAILED DESCRIPTION

A connected grid mesh may help energy, power, water, and other utilities get more value from the network, digital grid, and critical infrastructure. The power consumption of a solution is a critical network characteristic since there may be thousands of devices in a large network scale, some of which are deployed in the outdoors with battery to supply the power.

In current connected grid mesh implementations the transmission power is static and configured per each device. When the connected grid mesh is running under fixed physical rate transmission, each device sends its pre-configured transmission power with every packet. When it is running under adaptive modulation, each device sends out packets with the pre-set maximum transmission power of currently chosen modulation/data rates. This causes unnecessarily high power consumption and side impact since unnecessarily strong radio signals in peer communication introduce no more benefit for reception but increases power consumption. Moreover, a strong radio signal might even cause the collision to impact other wireless peer communication in some cases. As illustrated in Figure 1 below, traffic between nodes A and B and nodes C and D on the same channel impact each other.

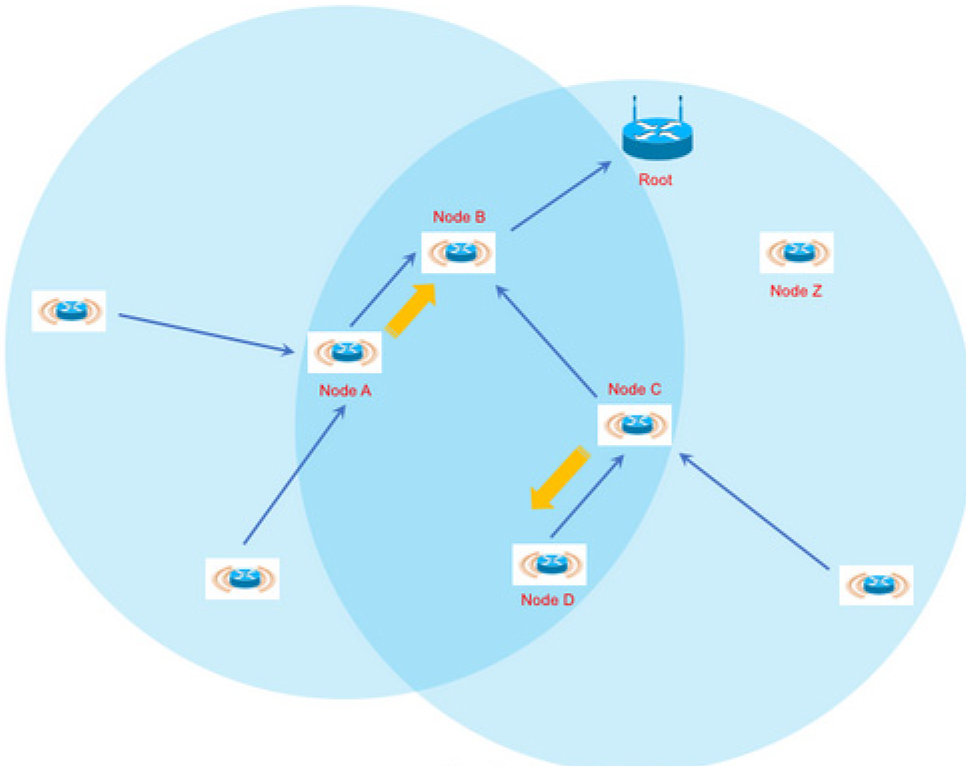


Figure1

On the other hand, in some situations, achieving network reliability also requires devices to increase their transmission power.

Accordingly, techniques are described herein to intelligently adjust the transmission power to achieve the reliability of the communication with efficient power consumption. This enables dynamic and intelligent adjustment of transmission power in a connected grid mesh, which reduces power consumption while guaranteeing the reliability of the network.

Connected grid mesh has three type of transmissions: unicast, broadcast, and asynchronized (async). In unicast, a sender transmits packets to the receiver via the receiver's unicast channel. In broadcast, a sender transmits packets in a Personal Area Network (PAN)-wide broadcast channel. In async, a sender transmits packets on all channels in a specific sequence, which allows all neighbors to receive the packet using channel hopping. The beacon request frame may use this pattern to transmit (e.g., PAN Advertisement (PA), PAN Configure (PC), PAN Advertisement Request (PAS), and PAN Configuration Request (PCS)).

These techniques include two parts to achieve reliability of communication with efficient power consumption. First, adjust the transmission power in the connected grid mesh based on the type of transmission. Second, adjust the transmission power in the connected grid mesh based on the wireless radio environment situation.

In current implementations, all devices in the connected grid mesh are pre-set with two parameters: Received Signal Strength Indication (RSSI) of each physical data rate and the maximum transmission power of each physical data rate. In one example, Orthogonal Frequency-Division Multiplexing (OFDM) is 800kbps, RSSI sensitivity is -101dBm, and maximum transmission power is 28dBm to demonstrate.

During the device join state, it may send joining requests PAS and PCS with async transmission, to make sure all reachable neighbors have the chance to receive the request and reply. The PAS/PCS packet may be transmitted at the maximum transmission power of the chosen data rate. This is illustrated in Figure 2 below as the communication between node Z and the root node.

When radio neighbors reply to the PAS and PCS it sends out PA and PC. It calculates the proper transmission power from the received PAS/PCS RSSI and known maximum transmission power. Such proper transmission power of the async packet may ensure the joining device is capable of receiving this packet beyond the sensitivity of receiving signal level in the meantime to limit unnecessary congestion with another peer communication. This is also illustrated in Figure 2 below as the communication between node Z and the root node.

Transmission	Tx Power/dBm	RSSI of Receiver
Z - > Root	28	-70
Root -> Z	7	-92

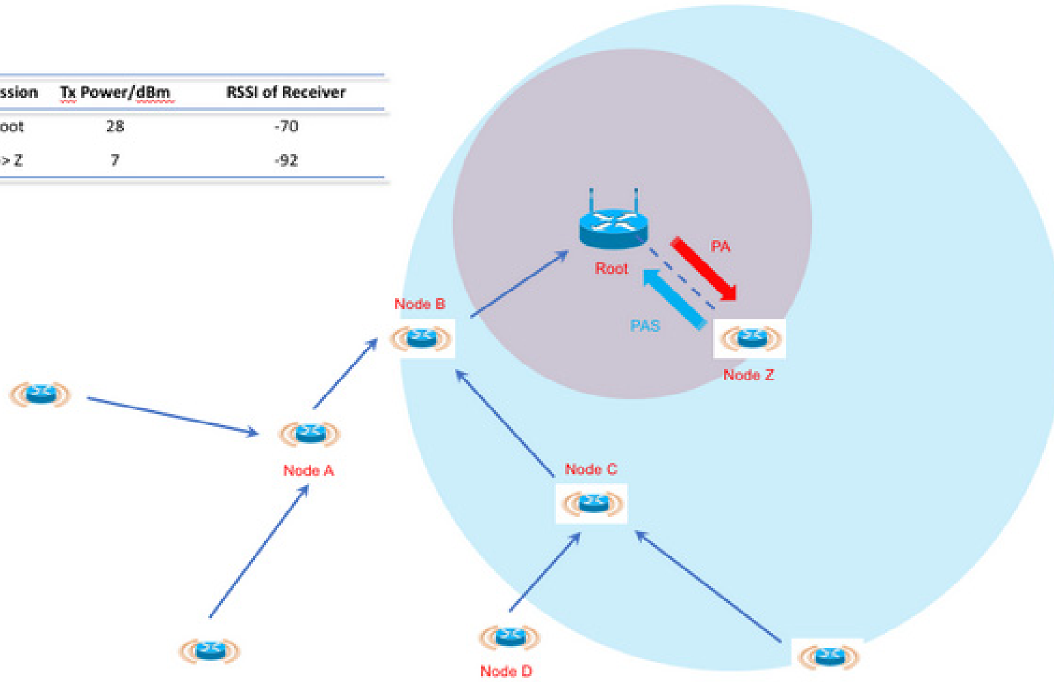


Figure2

As illustrated in Figure 3 below, broadcast transmission in a PAN broadcast channel may use the maximum transmission power so that a maximum broad range of nodes may receive the packets.

Transmission	Tx Power/dBm	RSSI of Receiver
Unicast C - > B	20	-96
Unicast C - > D	10	-95
Broadcast C-> all	28	

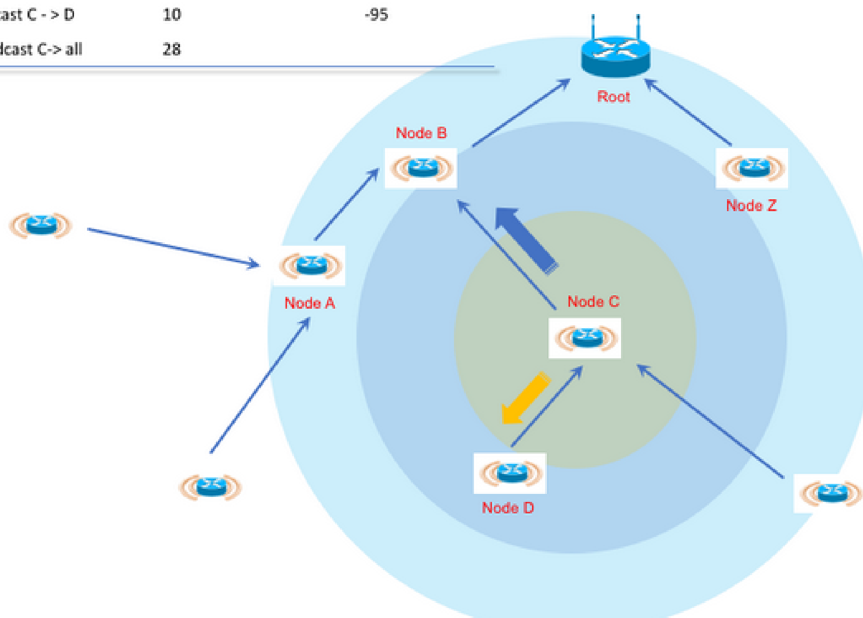


Figure3

With respect to unicast transmission between peers, for each unicast packet the receiver generates, a corresponding acknowledge frame includes the RSSI IE indicating the signal level when this packet is received. The sender receiving the acknowledge frame may adjust its transmission power to the peer. In particular, the first unicast packet to specific peer may be sent with a maximum transmission power. With RSSI from the IE of the acknowledge frame, the target of transmission power adjustment guarantees the packet would be received not far beyond the receiver's sensitivity. Considering the fluctuation of transmission power and RSSI measurement, a threshold (e.g., 5dbm) may be set. The transmission power to each peer device may be recorded, as illustrated in Figure 3 above.

When radio Packet Error Rate (PER) increases, if the sender has not received the acknowledge frame, it increases transmission power in the packet retransmission process. As illustrated in Figure 4, retransmission power incrementation may be different based on packet Quality of Service (QoS) priority.

Transmission	Tx Power/dBm (retry#)
A -> B(Low)	12(0)->14(1)->18(2)->26(3)...
C -> B (High)	15(0)->19(1)->28(2)...

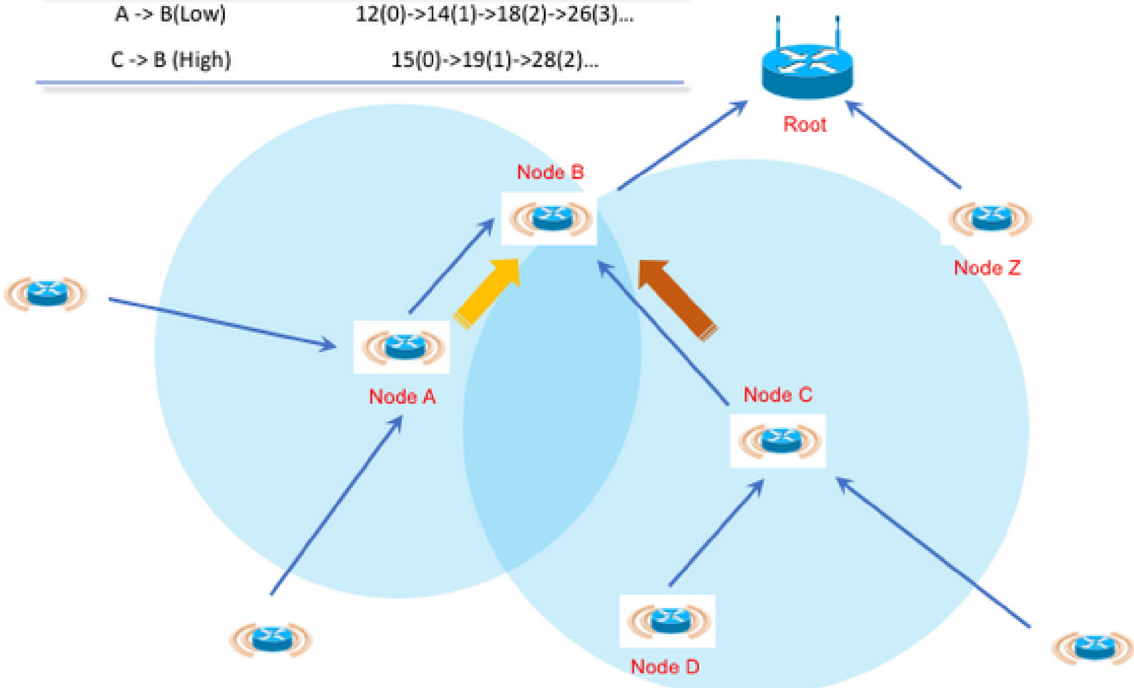
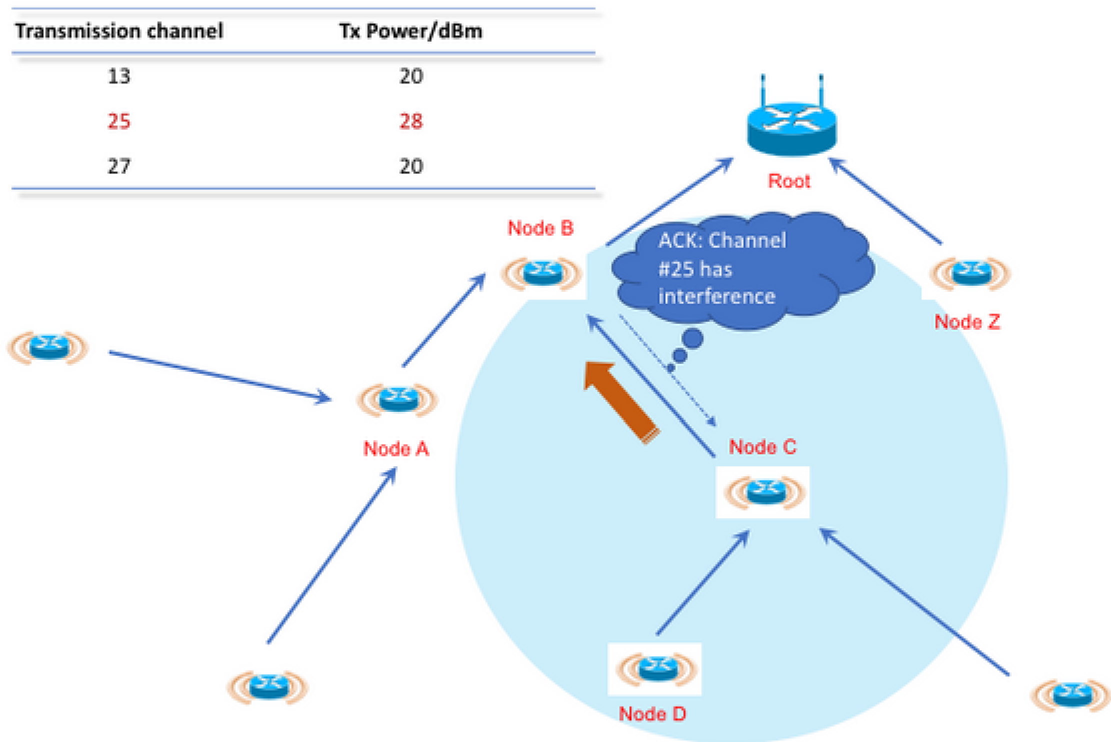


Figure4

The receiver defines a set of interference patterns and if it detects the interference on some channels, it may inform its unicast transmission peer in the acknowledge frame.

As illustrated in Figure 5, using this indication the sender may increase the transmission power to the receiver on these channels to compete against the interference.



Transmission channel	Tx Power/dBm
13	20
25	28
27	20

Figure5

In summary, techniques are provided herein for intelligent transmission power control under different transmission patterns in a connected grid mesh. The transmission patterns include asynchronized transmission, broadcast transmission, and unicast transmission. They also provide a mechanism to help data packets compete against interference on specific channels and help high priority QoS packet have a greater chance to be received when congestion occurs. This enables the connected grid mesh to achieve higher reliability of communication with efficient power consumption.