Next Generation Head of Train – End of Train (NGHE) Channel Access

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NGHE Communication Overview

1. Communication between a radio in the locomotive referred to as “Head of Train” or HOT and a radio mounted at the end of the last car of the train and is referred to as “End of Train” or EOT, is used for safety purposes. A major function of HOT to EOT communication is the delivery of a train stoppage command from HOT to EOT.
2. The HOT antenna is mounted on the locomotive roof with good line of sight to the surrounding area. The EOT antenna is obstructed by the rear wall of the last car and quite often has no line of sight to the surrounding area.
3. Many trains may be in range of each other. This is for example the case in a railroad yard. When multiple trains are in range, HOT to EOT communication employing the same communication channels, may interfere with each other. For example, 2 x 12.5 kHz channels are used today in the US to serve all EOT to HOT communication. One of these channels is used for HOT to EOT communication and the other is used for EOT to HOT communication. In the future, both 12.5 kHz channels may be used for two-way communication. The arrangement in which one channel is used for HOT to EOT communication and another channel is used for EOT to HOT communication is referred to as “Duplex”. The arrangement in which the same channel is used for two-way communication is referred to as “Simplex”.
4. Interference between EOT-HOT communication of multiple trains can be minimized by employing CSMA/CA channel access, i.e., EOT and HOT radios on all trains, are only transmitting when the channel is idle. For CSMA/CA to be effective, each HOT and EOT radios need to have good connectivity to all other EOT and HOT radios so that they can detect if any other radio is transmitting. The scenario in which this condition is not met is referred to as the “hidden node problem”, i.e., one or more of the radios are unable to detect transmission by one or more of the other radios. Given the EOT poor connectivity to its surrounding area, the EOT is highly likely to be hidden from some of the other radios.
5. This document describes a solution to the hidden EOT problem. The solution relies on the characteristics of NGHE message communication as follows:
    a. Most of the EOT messages are transmitted by the EOT in response to a command received from HOT.
    b. There are multiple types of message transactions between HOT and EOT. The type of transaction can be decoded from the command message transmitted by HOT.
    c. The communication parameters of the transaction, e.g., Modulation and Coding Scheme and Repetition factors, can also be decoded from the command message transmitted by the hot.

d. Leveraging b and c above, the HOT decoding a command message of another HOT, can compute the duration of the entire transaction. Here are two transactions type examples:
    i. Massage transaction without positioning: this is a two-message transaction including a Command message from HOT to EOT and a Status message with no positioning from EOT to HOT.
    ii. Message transaction with positioning: this is a three- message transaction including a Command message from HOT to EOT, A Status message with positioning from EOT to HOT and an ACK message from HOT to EOT.

Each of these message transactions along with the parameters of communication can be translated into the duration of the transaction.

Simplex Channel Access

1. Both HOT and EOT perform CSMA/CA. Sensing is performed against the RX frequency (which for Simplex, equals the TX frequency).
2. A deferral mechanism is used to minimize the probability of collisions, especially when the EOT is hidden from some of the other links. This mechanism runs at the HOT in addition to the basic CSMA/CA mechanism that runs in both EOT and HOT:
    a. The HOT monitors NGHE commands of all NGHE links in range. When an NGHE command of another HOT is detected, the HOT suspends its transmission for a period equal to the duration of the entire message transaction.
    b. The HOT may also decode a status message transmitted by a foreign EOT and defer transmission for the remaining duration of the transaction.
    c. The HOT will identify a message as being transmitted by a foreign HOT or EOT by looking at the id of the sender in the message header.
    d. The HOTs will typically have line of sight, i.e., the likelihood of a hidden HOT is small. The EOT acts in response to a HOT command, and as such, a hidden EOT is resolved by its master HOT.

Duplex Channel Access

1. Both HOT and EOT perform CSMA/CA. Sensing in the HOT is done in the HOT to EOT communication channel. It may also be done in the EOT to HOT communication channel but given the deferral mechanism described below; this is not necessary.
2. When the HOT wants to transmit, it tunes its receiver to the HOT to EOT communication channel, performs the sensing and transmits the message if the HOT to EOT channel is idle. The HOT tunes its receiver to the EOT to HOT channel

only during the message transaction with the EOT. At any other time, the HOT receiver is tuned to the HOT to EOT channel so that it can detect Command messages transmitted by foreign HOTs. When the EOT wants to transmit, it tunes its receiver to the EOT to HOT communication channel, perform the sensing and transmit the message if the EOT to HOT channel is idle. At any time other than prior to message transmission, the EOT receiver is tuned to the HOT to EOT communication.