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ADAPTIVE TONE MAP REQUEST CONTROL IN POWER LINE COMMUNICATION MESH NETWORK

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ABSTRACT

Techniques are provided herein for a sliding window mechanism to adjust the \textit{macMaxAgeTime} dynamically to adapt to different environmental conditions. This solution can greatly reduce issues caused by a fixed \textit{macMaxAgeTime}, such as communication failure due to tone map parameters not being updated, or valuable bandwidth being wasted due to needless tone map request/response. Consequently, this improves data throughput and network robustness of the whole system.

DETAILED DESCRIPTION

The Institute of Electrical and Electronics Engineers (IEEE) P1901.2 working group is actively standardizing the PHY / Media Access Control (MAC) address of a Power Line Communication (PLC) link-layer targeted at Smart Utility Networks (SUNs). To help achieve greater throughput and robustness in a noisy environment, IEEE P1901.2 relies on Orthogonal Frequency Division Multiplexing (OFDM). OFDM utilizes additional bandwidth by allowing transmission of multiple data streams across orthogonal subcarriers simultaneously to increase throughput.

Adaptive Tone Mapping (ATM) is a process that dynamically selects which subcarriers and coding parameters to use when transmitting a frame. The goal of ATM is to maximize overall throughput by choosing a modulation and identifying subcarriers that offer an acceptable Signal-to-Noise Ratio (SNR). Adjusting the modulation, code-rate, and number of subcarriers can vastly change the effective throughput of the link.

IEEE P1901.2 currently specifies the ATM process as follows. First, when sending a frame to a neighboring node, the neighbor’s entry is found in the neighbor table and the ATM parameters (i.e., modulation, code-rate, and subcarriers) are obtained. Second, if no neighbor table entry exists or the neighbor’s age parameter exceeds a threshold, the ATM
parameters are initialized to ROBO mode (i.e., the slowest data rate possible using all subcarriers). Also, the Tone Map Request (TMREQ) bit in the frame’s header is set.

Third, when receiving a frame with the TMREQ bit set, the SNR is evaluated across all subcarriers. The modulation, code-rate, and subcarrier set are chosen to maximize the overall throughput. The parameters are provided back to the source in a Tone Map Response (TMRES) frame. Fourth, when receiving a TMRES frame, the ATM parameters are stored in the neighbor table and the age value is reset.

Nodes in PLC or dual-PHY (Radio Frequency (RF) and PLC) mesh networks need to start the ATM process at regular intervals.

IEEE P1901.2 requires any frame with the TMREQ bit set to be sent utilizing ROBO or Super ROBO mode (e.g., Binary Frequency Shift Keying (2-FSK) modulation with Reed-Solomon with repetition coding across all sub-carriers) which offers the slowest data rate (2.4 kbps in the European Committee for Electrotechnical Standardization (CENELEC) A band). The benefit of using ROBO mode is it (1) maximizes the effective range and (2) allows the receiver to evaluate the SNR across all subcarriers. However, this is done at the cost of minimizing overall throughput.

The interval to start the ATM process usually depends on the age parameters (e.g., $macMaxAgeTime$ as defined in IEEE 1901.2-2013).

Figure 1 below illustrates an example system.
One question is how often the nodes start the ATM process. If nodes use a big \( \text{macMaxAgeTime} \), they may not have the correct ATM parameters to send data packets and will cause data transmission failure. If nodes use a small \( \text{macMaxAgeTime} \), they can use the correct ATM parameters to send data packets successfully. However, ATM requests and responses are sent in ROBO or Super ROBO modulations which offers the lowest data rate. This will cost much valuable PLC bandwidth and degrade the whole system data throughput, especially in a network with thousands of nodes. In addition, the environmental conditions such as noise or interference varies over times and as such starting the ATM process at a fixed \( \text{macMaxAgeTime} \) is not appropriate.

One goal is to provide an efficient mechanism to adjust the \( \text{macMaxAgeTime} \) to request ATM parameters depending on different situations. As such, a sliding window is described for adjusting the interval parameter \( \text{macMaxAgeTime} \) dynamically according to different environmental conditions. In good SNR environment, the ATM may vary slowly or not change, but in bad SNR environments, these tone map parameters may vary widely. The \( \text{macMaxAgeTime} \) will be different in different situations. In good SNR environments, the \( \text{macMaxAgeTime} \) will be big, while in bad SNR environments it will be small. The sliding window is designed to adjust the \( \text{macMaxAgeTime} \) smoothly to adapt to different situations.

One example of a sliding window is \([2^n, 2^{n+1}, 2^{n+2}, \ldots, 2^{n+m}]\). At a first example step, nodes set the \( \text{macMaxAgeTime} \) to \( 2^n \times \text{macMinAgeTime} \). The \( \text{macMinAgeTime} \) is a predefined variable. At a second example step, when the timer fires, nodes set the TMREQ bit in the outgoing packet to request the neighbor’s ATM information. At a third example step, the nodes get the TMRES and check the ATM parameters. If the ATM parameters are not changed, \( \text{counter}_\text{unchanged} \) is incremented by one, and if \( \text{counter}_\text{unchanged} > N_{\text{up}} \), the nodes move to the next step of the sliding window, setting \( \text{macMaxAgeTime} \) to \( 2^{n+1} \times \text{macMinAgeTime} \). If the ATM parameters are changed, \( \text{counter}_\text{changed} \) is incremented by one, and if \( \text{counter}_\text{changed} > N_{\text{down}} \), the nodes move back one step. At a fourth example step, the third example step is repeated until the nodes get to the maximum step \( 2^{n+m} \), or the minimum step \( 2^n \). The parameters \( n, m \) and \( \text{macMinAgeTime} \) may be configurable to balance performance, network scale, and environmental conditions.
Figure 2 below illustrates an example flowchart.

![Flowchart](image)

*Figure 2*

In summary, techniques are provided herein for a sliding window mechanism to adjust the `macMaxAgeTime` dynamically to adapt to different environmental conditions. This solution can greatly reduce issues caused by a fixed `macMaxAgeTime`, such as communication failure due to tone map parameters not being updated, or valuable bandwidth being wasted due to needless tone map request/response. Consequently, this improves data throughput and network robustness of the whole system.