Claims

What is claimed is:

1. A method performed by an endpoint device in a mesh network for adjusting a frequency of a crystal oscillator of the endpoint device, the method comprising:

while operating in an initial communication mode,

receiving a reference timing signal synchronized to a high-accuracy clock over a mesh network from a reference device in the mesh network;

obtaining a current value of a frequency of the crystal oscillator of the endpoint device;

determining a frequency difference between a reference frequency of the reference timing signal and the current value of the frequency;

generating a control signal based on the frequency difference;

adjusting the frequency of the crystal oscillator according to the control signal; and

determining that an error of the frequency of the crystal oscillator satisfies a pre-determined condition;

in response to determining that an error of the frequency of the crystal oscillator satisfies a pre-determined condition, switching to a narrowband or ultra-narrowband communication mode, wherein a data rate of the narrowband or ultra-narrowband communication mode is lower than a data rate of the initial communication mode; and

transmitting to and receiving communication signals from another device in the mesh network using an oscillating signal generated by the crystal oscillator while operating in the narrowband or ultra-narrowband communication mode.

2. The method of claim 1, wherein the control signal is a voltage control signal generated with a voltage value in proportion to the frequency difference.

3. The method of claim 2, wherein the voltage control signal is generated based on a voltage reference signal.

4. The method of claim 1, further comprising:

while operating in the narrowband or ultra-narrowband communication mode,

receiving a reference timing signal over the mesh network from the reference device;

obtaining an updated current value of the frequency of the crystal oscillator;

determining an updated frequency difference between the reference frequency and the updated current value of the frequency;

generating a second control signal based on the updated frequency difference;

adjusting the frequency of the crystal oscillator according to the second control signal; and

transmitting to and receiving communication signals from the another device using the oscillating signal generated by the crystal oscillator.

5. The method of claim 1, wherein the threshold value is determined based, at least in part, upon a bandwidth of the narrowband or ultra-narrowband communication mode.

6. The method of claim 1, wherein the crystal oscillator is a voltage-controlled temperature-compensated crystal oscillator (VCTCXO).

7. The method of claim 1, wherein the reference timing signal is transmitted from the reference device to the endpoint device according to a protocol following IEEE 802.15.4g.

8. A system, comprising:

a reference device configured for transmitting a reference timing signal to a plurality of endpoint devices in a mesh network; and

the plurality of endpoint devices, each endpoint device of the plurality of endpoint devices configured for:

while operating in an initial communication mode,

receiving the reference timing signal synchronized to a high-accuracy clock over the mesh network from the reference device;

obtaining a current value of a frequency of a crystal oscillator of the endpoint device;

determining a frequency difference between a reference frequency of the reference timing signal and the current value of the frequency of the crystal oscillator;

generating a control signal based on the frequency difference;

adjusting, according to the control signal, the crystal oscillator to adjust the frequency of the crystal oscillator; and

determining that an error of the frequency of the crystal oscillator satisfies a pre-determined condition;

in response to determining that an error of the frequency of the crystal oscillator satisfies a pre-determined condition, switching to a narrowband or ultra-narrowband communication mode, wherein a data rate of the narrowband or ultra-narrowband communication mode is lower than a data rate of the initial communication mode; and

communicating with the reference device or another endpoint device in the mesh network using an oscillating signal generated by the crystal oscillator while operating in the narrowband or ultra-narrowband communication mode.

9. The system of claim 8, wherein the reference device is further configured to receive the reference timing signal from a global position system (GPS).

10. The system of claim 8, wherein the control signal is a voltage control signal generated with a voltage value in proportion to the frequency difference.

11. The system of claim 10, wherein the voltage control signal is generated based on a voltage reference signal.

12. The system of claim 8, wherein the endpoint device is further configured for:
while operating in the narrowband or ultra-narrowband communication mode,

receiving a reference timing signal over the mesh network from the reference device;

obtaining an updated current value of the frequency of the crystal oscillator;

determining an updated frequency difference between the reference frequency and the updated current value of the frequency;

generating a second control signal based on the updated frequency difference;

adjusting the frequency of the crystal oscillator according to the second control signal; and

transmitting to and receiving communication signals from the reference device or the another endpoint device using the oscillating signal generated by the crystal oscillator.

13. The system of claim 8, wherein the threshold value is determined based, at least in part, upon a bandwidth of the narrowband or ultra-narrowband communication mode.

14. The system of claim 8, wherein the crystal oscillator is a voltage-controlled temperature-compensated crystal oscillator (VCTCXO).

15. An endpoint device of a network, comprising:

a crystal oscillator configured for generating an oscillating signal with a frequency of the crystal oscillator;

a processor configured to execute computer-readable instructions; and

a memory configured to store the computer-readable instructions that, when executed by the processor, cause the processor to perform operations comprising:

while operating in an initial communication mode,

receiving a reference timing signal synchronized to a high-accuracy clock over the network from a reference device in the network;

obtaining a current value of the frequency of the crystal oscillator;

determining a frequency difference between a reference frequency of the reference timing signal and the current value of the frequency of the crystal oscillator;

causing a control signal to be generated based on the frequency difference;

adjusting the frequency of the crystal oscillator by applying the control signal to the crystal oscillator; and

determining that an error of the frequency of the crystal oscillator satisfies a pre-determined condition;

causing the endpoint device to switch to a narrowband or ultra-narrowband communication mode in response to determining that an error of the frequency of the crystal oscillator satisfies a pre-determined condition, wherein a data rate of the narrowband or ultra-narrowband communication mode is lower than a data rate of the initial communication mode; and

while operating in the narrowband or ultra-narrowband communication mode, causing the endpoint device to communicate with another device in the network using an oscillating signal generated by the crystal oscillator.

16. The endpoint device of claim 15, wherein the control signal is a voltage control signal generated with a voltage value in proportion to the frequency difference.

17. The endpoint device of claim 16, wherein the voltage control signal is generated based on a voltage reference signal.

18. The endpoint device of claim 15, the operations further comprise:

while operating in the narrowband or ultra-narrowband communication mode,

receiving a reference timing signal over the network from the reference device;

obtaining an updated current value of the frequency of the crystal oscillator;

determining an updated frequency difference between the reference frequency and the updated current value of the frequency;

causing a second control signal to be generated based on the updated frequency difference;

adjusting the frequency of the crystal oscillator by applying the second control signal to the crystal oscillator; and

causing the endpoint device to communicate with another device in the network using the oscillating signal generated by the crystal oscillator.

19. The endpoint device of claim 15, wherein the threshold value is determined based, at least in part, upon a bandwidth of the narrowband or ultra-narrowband communication mode.

20. The endpoint device of claim 15, wherein the crystal oscillator is a voltage-controlled temperature-compensated crystal oscillator (VCTCXO).