

CLAIMS

WHAT IS CLAIMED IS:

1. A method for maintaining synchronization of nodes in a mesh network, the method comprising:

receiving, by a receiving node, primary beacons from a first transmitting node during a predetermined time interval, each of the primary beacons comprising time information indicating a time that a respective primary beacon was transmitted, the receiving node having a primary association with the first transmitting node;

comparing the time that each of the primary beacons was transmitted with a time that each of the primary beacons was received as indicated by a clock in the receiving node to determine a time difference;

accumulating the time difference for each primary beacon received from the first transmitting node during the predetermined time interval to generate a first time synchronization error;

comparing the first time synchronization error to an upper limit threshold value; and

in response to determining that the first time synchronization error exceeds the upper limit threshold value, transmitting a first request to the first transmitting node to increase a rate of beacon transmissions for a specified period of time;

wherein the upper limit threshold value is configurable as a programmable value.

2. The method of claim 1, wherein accumulating the time difference comprises adding each determined time difference as a signed integer value.

3. The method of claim 1, further comprising:

determining, by the receiving node, a second time synchronization error after the specified period of time for receiving beacons at an increased rate expires; and

in response to determining that the second time synchronization error exceeds the upper limit threshold value, transmitting a second request to the first transmitting node to increase the rate of beacon transmissions.

4. The method of claim 3, wherein the receiving node is prohibited from transmitting additional requests during the specified period of time.
5. The method of claim 1, further comprising:
 - comparing the first time synchronization error to a second threshold value; and
 - in response to determining that the first time synchronization error exceeds the second threshold value, transmitting a notification to a central system.
6. The method of claim 1, further comprising:
 - receiving, by the receiving node, secondary beacons from a second transmitting node during the predetermined time interval, each of the secondary beacons comprising time information indicating a time that a respective secondary beacon was transmitted, the receiving node having a secondary association with the second transmitting node;
 - comparing the time that each of the secondary beacons was transmitted with a time that each of the secondary beacons was received as indicated by the clock in the receiving node to determine a time difference;
 - accumulating the time difference for each secondary beacon received from the second transmitting node during the predetermined time interval to generate a second time synchronization error;
 - comparing the second time synchronization error to the first time synchronization error;
 - and
 - in response to determining that the first time synchronization error is greater than the second time synchronization error, causing the receiving node to change the primary association from the first transmitting node to the second transmitting node.
7. A network device, comprising:
 - a clock configured to keep a local time;
 - a memory configured to store data and instructions;
 - a radio configured to communicate with a mesh network; and
 - a processor in communication with the clock, the memory, and the radio, the processor configured to:
 - receive, via the radio, primary beacons from a first transmitting node during a predetermined time interval, each of the primary beacons comprising time information indicating a time that a respective primary beacon was transmitted, the network device having a primary association with the first transmitting node;

compare the time that each of the primary beacons was transmitted with a time that each of the primary beacons was received as indicated by the clock to determine a time difference;

accumulate the time difference for each primary beacon received from the first transmitting node during the predetermined time interval to generate a first time synchronization error;

compare the first time synchronization error to an upper limit threshold; and

in response to determining that the first time synchronization error exceeds the upper limit threshold, transmit, via the radio, a first request to the first transmitting node to increase a rate of beacon transmissions, wherein the upper limit threshold value is configurable as a programmable value.

8. The network device of claim 7, further comprising a first counter, wherein the first counter is configured to accumulate the time difference for the primary beacons by adding each determined time difference as a signed integer value.

9. The network device of claim 7, wherein the processor is further configured to:
receive, via the radio, the primary beacons from the first transmitting node at an increased beacon transmission rate for a specified period of time based on the first request, wherein the increased beacon transmission rate ends when the specified period of time expires.

10. The network device of claim 9, wherein the processor is further configured to:
in response to determining that the first time synchronization error exceeds the upper limit threshold after the specified period of time expires, transmit a second request to the first transmitting node to increase the rate of beacon transmissions.

11. The network device of claim 10, wherein the processor is further configured to:
prohibit the network device from transmitting additional requests during the specified period of time.

12. The network device of claim 7, wherein the processor is further configured to:
compare the first time synchronization error to a second threshold; and
in response to determining that the first time synchronization error exceeds the second threshold, transmit a notification to a central system.

13. The network device of claim 7, wherein the processor is further configured to:

- receive secondary beacons from a second transmitting node during the predetermined time interval, each of the secondary beacons comprising time information indicating a time that a respective secondary beacon was transmitted, the network device having a secondary association with the second transmitting node;
- compare the time that each of the secondary beacons was transmitted with a time that each of the secondary beacon was received as indicated by the clock to determine a time difference;
- accumulate the time difference for each secondary beacon received from the second transmitting node during the predetermined time interval to generate a second time synchronization error;
- compare the second time synchronization error to the first time synchronization error;
- and
- in response to determining that the first time synchronization error exceeds the second time synchronization error, change the primary association of the network device from the first transmitting node to the second transmitting node.

14. The network device of claim 13, further comprising a second counter, wherein the second counter is configured to accumulate the time difference for the secondary beacons by adding each determined time difference as a signed integer value.

15. A non-transitory computer readable medium having stored therein instructions for making one or more processors of a receiving node execute a method for maintaining synchronization of nodes in a mesh network, the processor executable instructions comprising instructions for performing operations including:

- receiving primary beacons from a first transmitting node during a predetermined time interval, each of the primary beacons comprising time information indicating a time that a respective primary beacon was transmitted, the receiving node having a primary association with the first transmitting node;

- comparing the time that each of the primary beacons was transmitted with a time that each of the primary beacons was received as determined by a local clock to determine a time difference;

accumulating the time difference for each primary beacon received from the first transmitting node during the predetermined time interval to generate a first time synchronization error;

comparing the first time synchronization error to an upper limit threshold value; and

in response to determining that the first time synchronization error exceeds the upper limit threshold value, transmitting a first request to the first transmitting node to increase a rate of beacon transmissions, wherein the upper limit threshold value is configurable as a programmable value.

16. The non-transitory computer readable medium as defined in claim 15, further comprising instruction for performing operations including:

receiving the primary beacons at an increased beacon transmission rate for a specified period of time based on the first request, wherein the increased beacon transmission rate ends when the specified period of time expires.

17. The non-transitory computer readable medium as defined in claim 16, further comprising instruction for performing operations including:

in response to determining that the first time synchronization error exceeds the upper limit threshold value after the specified period of time expires, transmitting a second request to the first transmitting node to increase the rate of beacon transmissions.

18. The non-transitory computer readable medium as defined in claim 17, wherein additional requests are prohibited from being transmitted during the specified period of time.

19. The non-transitory computer readable medium as defined in claim 15, further comprising instruction for performing operations including:

comparing the first time synchronization error to second threshold value; and

in response to determining that the first time synchronization error exceeds the second threshold value, transmitting a notification to a central system.

20. The non-transitory computer readable medium as defined in claim 15, further comprising instruction for performing operations including:

receiving secondary beacons from a second transmitting node during the predetermined time interval, each of the secondary beacons comprising time information indicating a time that a respective secondary beacon was transmitted, the receiving node having a secondary association with the second transmitting node;

comparing the time that each of the secondary beacons was transmitted with a time that each of the secondary beacons was received to determine a time difference;

accumulating the time difference for each secondary beacon received from the second transmitting node during the predetermined time interval to generate a second time synchronization error;

comparing the second time synchronization error to the first time synchronization error;
and

in response to determining that the first time synchronization error exceeds the second time synchronization error, changing the primary association from the first transmitting node to the second transmitting node for receiving beacons.