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ADJUSTING NETWORK PARAMETERS DYNAMICALLY TO ACCELERATE MESH NETWORK CONVERGENCE

Yinfang Wang

Jim Lu

Chuanwei Li

Yajun Xia

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AUTHORS:
Yinfang Wang
Jim Lu
Chuanwei Li
Yajun Xia

ABSTRACT

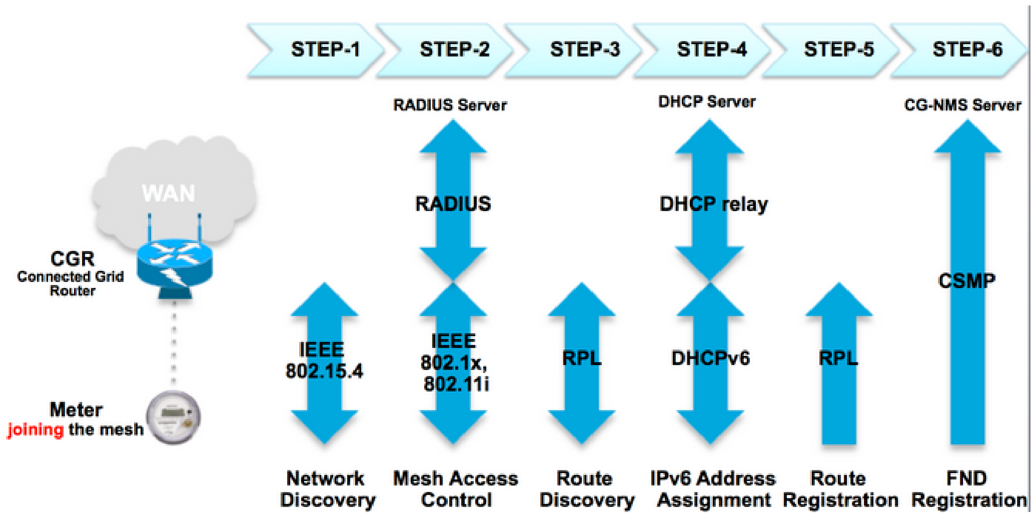
Techniques are described to adaptively adjust network parameters by adjusting the network scale. On one side, a smooth Clear Channel Assessment (CCA) mechanism may adaptively adjust the network scale to take precautions for collision. On the other side, a Cyclic Redundancy Check (CRC) mechanism may also automatically adjust the network scale to detect the collision. This may speed up network formation and convergence significantly, and maintain the network effectively.

DETAILED DESCRIPTION

In mesh networks, nodes take several stages to join a Personal Area Network (PAN). The stages may include discovering the network, security authentication, route discovery, Internet Protocol version 6 (IPv6) address assignment (e.g., Dynamic Host Configuration Protocol version 6 (DHCPv6)), route registration (e.g., Routing Protocol for Low-Power and Lossy Networks (RPL)), and Field Network Director (FND) registration.

Figure 1 below illustrates an example PAN.

Figure 1. Network Formation



In different network scenarios, in order to speed up network joining and network convergence and reduce collisions, the mesh network defines three network scales: small scale, middle scale, and large scale. Selection of network scale is based on the node number of target deployment in a PAN, as illustrated in Table 1 below.

Table 1. Selection of Network Scale with Target Node Number in a PAN

Network Scale Selection	Target Node Number
Small	[1,30]
Middle	[30, 150]
Large	[150, 150+]

Moreover, the different network parameters may correspond to different network scales, as illustrated in Table 2 below.

Table 2. Different Network Parameter Suits of Frames in Different Network Stage

Network Stage	Frame Type In Network	Network Parameter Suits (Small Scale [min, max])	Network Parameter Suits (Middle Scale [min, max])	Network Parameter Suits (Large Scale [min, max])
Discovering network	Discover Beacon Frame	[10, 60] seconds	[15, 60] seconds	[60, 900] seconds
	Sync Beacon Frame	[30, 60] seconds	[15, 60] seconds	[60, 900] seconds
Security authentication	EAPOL Key Frame	[60, 300] seconds	[60, 300] seconds	[300, 3600] seconds
IPv6 address assignment	Solicit Frame	[3, 3] seconds	[60, 3600] seconds	[60, 3600] seconds
Route registration	DIO Frame	[32, 1048] seconds	[1048, 16777] seconds	[1048, 16777] seconds
FND Registration	Coap Frame	[60, 300] seconds	[300, 3600] seconds	[300, 3600] seconds
Joining Timing		[195, 1771] seconds	[1498, 24397] seconds	[1828, 179600] seconds

In one example of a small scale network, during the "discovering network" phase, the sending time of the discover/sync beacon message in a small scale network is earlier than sending the timing of middle and large scale networks. As shown in Table 2, the minimum of the sending intervals are 10 seconds in the small scale, 15 seconds in the middle scale, and 60 seconds in the large scale. And the maximum of the sending times are 60 seconds, 60 seconds, and 900 seconds separately. A similar mechanism also applies to the other stages provided above. Finally, the earlier node sends a message in the current network stage, and the faster node enters into the following stage so that it can join a PAN quickly.

As a result, the minimum joining times are 195 seconds, 1498 seconds, and 1828 seconds respectively in the small, middle, and large scale networks shown in Table 2. And the maximum joining times are 1771 seconds, 24397 seconds, and 179600 seconds respectively in the different network scales.

One problem in current mesh networks is that the scale parameters are fixedly preconfigured with one of three scales by writing into the flash based on the target network. But the fixed scale pre-configuration cannot match the changing network environment.

If the target deployment network is large, each node in the factory is fixedly preconfigured for large scales. It takes a minimum join timing of 1828 seconds to join the network. The mesh network is often a multi-hop network. Moreover, its hop may include up to 20 hops or more. Finally, the minimum join timing of the deepest node is 10 hours and more to join in the network. But during the initial stage of network formation, there are only a few mesh nodes existing in the network. The preconfigured large scale nodes may lead to the longer joining time and network convergence.

In one example, there are two PANs: PAN 1 is preconfigured with a small scale network, and PAN 2 is preconfigured with a middle scale network. Some nodes cross two PANs. When the wireless environment varies, the nodes in PAN 1 may try to join PAN 2. That may lead to network congestion at the preconfigured middle scale network. The worst case is that the migrating nodes cannot join PAN 2. Moreover, existing nodes in PAN 2 may get lost from the current PAN.

A second problem is that, in a factory, each node is fixedly preconfigured with one of three scales by an external tool. When the preconfigured node is put into the unmatched scale configuration in the field deployment, extra human resources may be required to reprogram it again.

Accordingly, in view of existing defects of fixed network parameters configurations, described herein is a mechanism to adaptively adjust network parameters to speed up the network formation and convergence by adjusting the network scale. The adjusted network scale mechanism may be considering from the two perspectives of taking precautions for collisions and detecting collisions. On one hand, the smooth Clear Channel Assessment (CCA) mechanism described herein may adaptively adjust the network scale from the point view of taking precautions for collisions. On the other hand, the Cyclic Redundancy Check (CRC) mechanism described herein may also automatically adjust the network scale from the point view of detecting the collision.

In one example, the network parameters may be dynamically adjusted for speeding up network formation and coverage using the smooth CCA mechanism.

Currently, mesh networks use CCA for taking precautions for collision. Nodes perform CCA before transmission to reduce collisions with neighbors.

Here nodes record the smoothed CCA value in different network scales, as shown in equation (1) below. CCA*pre* is the history smoothed CCA, and CCA*cur* is the current CCA. Values n and m may be configured based on different applications. When nodes change the network scale, the smoothed CCA value may be reset as the instant CCA.

$$CCA_{smooth} = CCA_{pre} * n/m + CCA_{cur} * (m-n)/m \quad (1)$$

The steps for the CCA mechanism are as follows.

In a first example step, during the period of booting up in the network, nodes initialize the network scale as small. Nodes may be quicker to send different kinds of messages during previously mentioned phases (e.g., discovering network phase, security authentication phase, etc.). This may speed up the network joining process.

The smoothed CCA enables the dynamic network scale transition mechanism.

As time goes on, more and more nodes may join the network. This leads to an increased CCA value. When the smoothed CCA of nodes is greater than or equal to the CCA threshold, the nodes continuously transit the network scale upwards to the large scale, as shown in Table 3 below.

The wireless environment often varies. For example, some neighbor outage may occur. At night time, the signal is often better than daytime. When the smoothed CCA of the nodes is smaller than half of the CCA threshold, the nodes continuously transit the network scale downwards to small scale, as shown in Table 3 below.

Network Scale	Smoothed CCA	Trend
Small -> Middle	CCA*smooth* >= *CCAthreshold*	Upward
Middle -> Small	CCA*smooth* < *CCAthreshold / 2*	Downward
Middle -> Large	CCA*smooth* >= *CCAthreshold*	Upward
Large -> Middle	CCA*smooth* < *CCAthreshold / 2*	Downward

Table 3

As illustrated in Figure 2 below, there are about 600 nodes in a PAN. Based on the previously described mechanism, all nodes in the entire PAN are preconfigured as large scale.

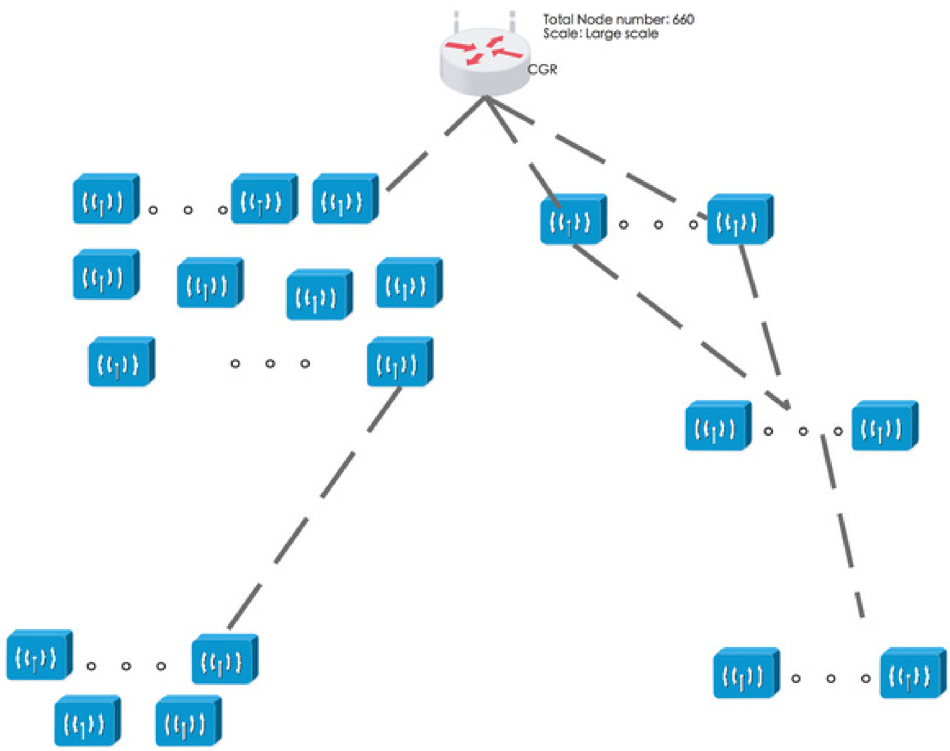


Figure 2. Large scale in a PAN

CCA not only reflects the wireless background, but also indirectly reflects the density of the neighborhood. By using the smooth mechanism described above, this PAN may be divided into n neighborhoods, each neighborhood having different numbers of nodes. Finally, all nodes in a PAN may dynamically build up the network with different network scales (small, medium, large), as illustrated in Figure 3 below.

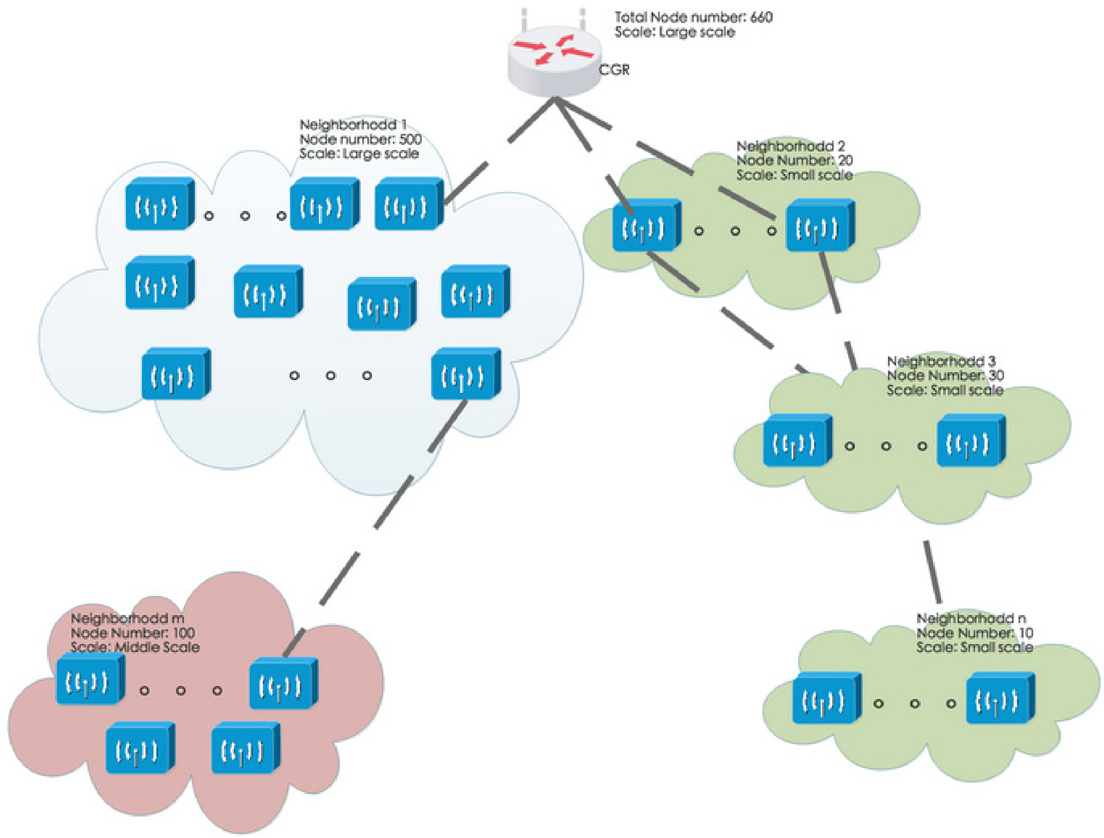


Figure 3. Different scales in a PAN

As shown in Table 4 below, nodes in small and medium network neighborhoods may join in the network quickly. Moreover, this accelerates the entire network formation and convergence.

In another example, a mechanism may adaptively adjust the network parameters for speeding up the network formation and coverage by the CRC mechanism.

Currently, mesh networks use CRC for detecting collisions. Mesh networks also uses the RPL protocol as the linked tree routing protocol. Every data message is transmitted in a fixed manner upward or downward. The nodes have more possibilities to meet the "hidden node" problem. When receiving corrupted messages of nodes due to conflicting information from neighbors, this can lead to CRC errors of received packets.

Nodes record a CRC error ratio during a period shown in equation (2). The period may be adjusted based on the packet numbering for maintaining the network.

$$Ratio_{err} = N_{err} / N_{rev} \quad (2)$$

Ratio*err* is a CRC errors ratio, N*err* is the total number of CRC error packets received during a period, and N*rev* is the total received number of packets during a period.

The steps involving the CRC mechanism are as follows.

During the period of booting up in the network, nodes initialize the network scale as small scale. This makes nodes quicker to send different kinds of messages during previously mentioned different phases (e.g., discovering network phase, security authentication phase, etc.). This may speed up the network joining process.

Based on the CCA error ratio, the network scale transition mechanism may operate among three kinds of scales.

Here the CRC error ratio threshold Ratio*threshold* may be adjusted by balancing the transition smoothly as a network scale transition. When the CRC error ratio of nodes is greater than or equal to the CRC error ratio threshold, the nodes are continuously transiting the network scale upwards to the large scale as shown in Table 3 above.

Because the wireless environment varies, when the CRC error ratio of nodes is smaller than half of CRC error ratio threshold, the nodes are continuously transiting the network scale downwards to small scale shown in Table 4 below.

Network Scale	CRC Error Ratio	Trend
Small -> Middle	*Ratioerr* >= Ratio*threshold*	Upward
Middle -> Small	*Ratioerr < Ratiothreshold / 2*	Downward
Middle -> Large	*Ratioerr >= Ratiothreshold*	Upward
Large -> Middle	*Ratioerr < Ratiothreshold / 2*	Downward

Table 4

Similar with CCA, CRC not only reflects the wireless background and indirectly reflects the density of the neighborhood. And CRC may also reflect the hidden neighbor collisions from this point of receiving the message. By using this CRC error ratio mechanism, the network in a PAN may build up the network with different network scales (small, medium, large), and maintain the network effectively.

These techniques enable adaptively adjusting network parameters for each node in the network. The overall network formation and convergence timing may be significantly shortened. Networks in a PAN may build up the network with different network scales (small, medium, large), and maintain the network effectively.

As described herein, the smooth CCA and CRC mechanisms may adaptively apply in each mesh node in the network. Moreover, the network parameters corresponding to different network scales may be adaptively adjusted on each mesh node to accelerate the entire network convergence. These techniques adaptively choose network parameters corresponding to different network scales based on existing CCA and CRC levels in the existing deployed field. This speeds up network formation by adaptively choosing different network scales by a CCA-assisted mechanism and CRC-assisted mechanism.

In summary, techniques are described to adaptively adjust network parameters by adjusting the network scale. On one side, a smooth CCA mechanism may adaptively adjust the network scale to take precautions for collision. On the other side, a CRC mechanism may also automatically adjust the network scale to detect the collision. This may speed up network formation and convergence significantly, and maintain the network effectively.