Wi-SUN Module FAN1.0 compliant

BP35C5 Application Manual

Version 1.0.8

Overview

This application manual describes how to use BP35C5 based on the common use cases of FAN. Refer to the User's Manual for more details regarding the commands used for every use case.

1. Table of Contents

2. Common Items 4
2.1. Terminology 4
3. Procedure in Replacing the Nodes 5
3.1. Replacement flow 7
3.2. How to replace 7
4. How to Verify the Routing 9
5. Remote Maintenance 10
6. Multicast Transmission 11
6.1. Multicasting to all neighboring nodes (ff02::1) 11
6.2. Multicasting to all neighboring routers (ff02::2) 12
6.3. Multicasting to all nodes on the same network (ff03::1) 12
6.4. Multicasting to all routers on the same network (ff03::2) 13
7. Build Multiple Networks in the Same Area 14
8. How to Use a Non-default Port for UDP/TCP 15
9. Notification of Transmission Completion 17
10. Connection Time 19
11. Power Consumption (for reference) 21
12. Throughput and latency (for reference) 23
12.1. TCP average throughput 23
12.2. UDP average throughput 24
12.3. TCP average latency 25
12.4. UDP average latency 26
12.5. Measuring method 27
13. Turnaround time (for reference) 28
13.1. TCP average turnaround time 28
13.2. UDP average turnaround time 28
13.3. Measuring method 29
14. Maximum number of connections 30
14.1. Configuration of maximum number of connection per Border Router 30
14.2. Configuration of maximum nunber of connection per Router 31
14.3. Configuration of maximum hops 32
15. Communication distance 33
15.1. Communication distance between building roofs 33
15.2. Communication distance on the ground 34
16. Antenna 35
16.1. Antenna switching 35
16.2. Diversity 36
17. Radio Law Certification 37
17.1. Japan 37
17.2. North America (FCC) 37
17.3. Others 38
18. Radio OFF Mode 39
18.1. How to switch 39

18.2. Notes on the init command 39
19. Transmission Power Setting 40
20. Parameters to be saved in non-volatile memory 41
21. Distance of connectable and communicable 43
21.1. Installation procedure at connectable distance 43
21.2. Confirmation of radio signal strength 44
21.3. Display contents of nebr command 44
22. Firmware update protocol 46
23. LED control 47
24. Notes 48
24.1. Wireless communication 48
24.2. Changes 48
24.3. Firmware 48
24.3.1. Firmware licensing 48
24.3.2. Firmware version 48
24.3.3. Method for checking firmware version 49
24.3.4. Current value and time 49
25. Revision History 50

2. Common Items

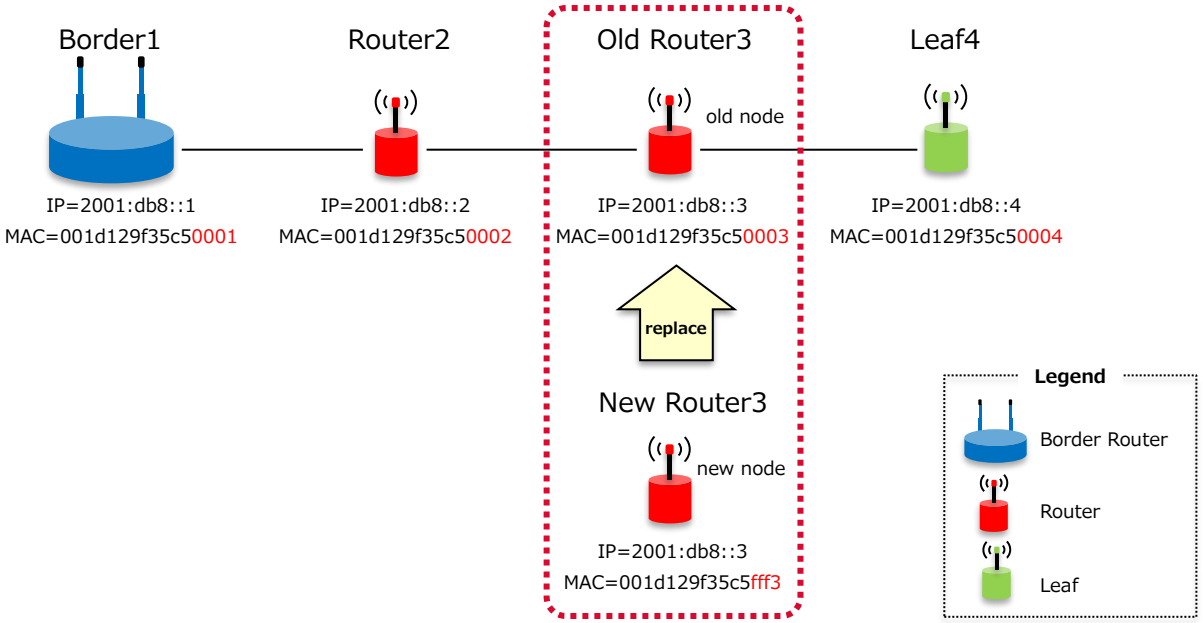
This chapter defines all common items of this manual.

2.1. Terminology

Terms	Description
Node	Terminal that configures the FAN network
Border Router	Parent node that manages the entire network
Router	Node with relay function
Leaf	Terminal node without relay function
Border	Short for Border Router
Routing	Communication path

3. Procedure in Replacing the Nodes

The following describes the replacement procedure when a node needs to be replaced because it is time to change it or due to malfunction.
In this chapter, the network below is used as an example.



In this example, the network type is a serial networking. However, the contents to implement are the same regardless of network type.

FAN distinguishes each node by MAC address. In this chapter, the lower 2 octets of MAC address are set to "000x", and compared to the node number to make it easier to distinguish between nodes. However, the new Router3 after replacement is set to "fff3" to easily differentiate it from the old Router3.

In order to explain the configuration of each node, the prompts are defined to clarify which node is being used.

Node Name	Prompt
Border1	BR1>
Router2	R2>
Old Router3	R3>
New Router3	R3N>
Leaf4	L4>

Here are the specific settings for each node:

Border1 settings

BR1> clear	Clear setting parameters
BR1> reset	Restart module
BR1> macf deny	Deny all MAC addresses
BR1> macf allow 001d129f35c50002	Allow MAC address of Router2
BR1> mode 1	Set profile mode to FAN profile mode
BR1> chan 33 59	Channel settings (using 33-59 channels)
BR1> ip 2001:db8::1/48	Set up your own (Border1) IP address and subnet mask
BR1> leaseip 001d129f35c50002 2001:db8::2	Set up IP address to lease to Router2
BR1> leaseip 001d129f35c50003 2001:db8::3	Set up IP address to lease to Router3
BR1> leaseip 001d129f35c50004 2001:db8::4	Set up IP address to lease to Leaf4
BR1> atstart 1	Set up operating mode at startup to Border Router
BR1> save	Save setting parameters
BR1> reset	Restart module

Router2 setting

R2> clear	Clear setting parameters
R2> reset	Restart module
R2> macf deny	Deny all MAC addresses
R2> macf allow 001d129f35c50001	Allow MAC address of Border1
R2> macf allow 001d129f35c50003	Allow MAC address of Router3
R2> mode 1	Set up profile mode to FAN profile mode
R2> chan 33 59	Channel settings (using 33-59 channels)
R2> atstart 2	Set up operating mode at startup to Router
R2> save	Save setting parameters
R2> reset	Restart module

Old Router3 settings

R3> clear	Clear setting parameters
R3> reset	Restart module
R3> macf deny	Deny all MAC addresses
R3> macf allow 001d129f35c50002	Allow MAC address of Router2
R3> macf allow 001d129f35c50004	Allow MAC address of Leaf4
R3> mode 1	Set up profile mode to FAN profile mode
R3> chan 33 59	Channel settings (using 33-59 channels)
R3> atstart 2	Set up operating mode at startup to Router
R3> save	Save setting parameters
R3> reset	Restart module

Leaf4 settings

L4> clear	Clear setting parameters
L4> reset	Restart module
L4> macf deny	Deny all MAC addresses
L4> macf allow 001d129f35c50003	Allow MAC address of Router3
L4> mode 1	Set up profile mode to FAN profile mode
L4> chan 33 59	Channel settings (using 33-59 channels)
L4> atstart 3	Set up operating mode at startup to Leaf
L4> save	Save setting parameters
L4> reset	Restart module

3.1. Replacement flow

The replacement flow is enumerated as follows.

① Delete the information of the old node, and add the information of the new node in the Border.
② Set the parameters of the old node to the new node, and replace the old node with the new node.
③ Delete the information of the old node and add the information of the new node in the neighboring nodes. (This is required only if the neighboring node is configured to be aware of the replacement target node.)

In replacing a node, it is necessary to configure not only the settings of the new node but also the settings of Border that manages the entire FAN network, and the settings of neighboring nodes (if needed).
In this example, Border1, Router2, Leaf4, and new Router3 are the targets.
There is no need to change the settings because the old Router3 will be stopped only.

3.2. How to replace

In here, the details of replacement procedure will be explained.

① Delete the information of the old node, and add the information of the new node in the Border.
Delete the information from the old Router3, which is managed by the Border and add the information of the new Router3.

```
BR1> fnode del 001d129f35c50003              ← delete node information of old Router3
BR1> leaseip del 001d129f35c50003            ← delete IP address information of old Router3
BR1> leaseip 001d129f35c5fff3 2001:db8::3    ← add IP address information of new Router3
```

② Set the parameters of the old node to the new node, and replace the old node with the new node.
Set the parameters configured in the old Router3 as they are in the new Router3.

```
R3N> clear
R3N> reset
R3N> macf deny
R3N> macf allow 001d129f35c50002
R3N> macf allow 001d129f35c50004
R3N> mode 1
R3N> chan 33 59
R3N> atstart 2
R3N> save
R3N> reset
```

Once configured, stop the old Router3 and install the new Router3. This step completes the physical replacement.

③ Delete the information of the old node and add the information of the new node in the neighboring nodes.
This setting is not necessary unless the neighboring node is configured to be aware of the replacement target node.
In this example, the information from the old node is deleted and the information of the new node is added because MAC address filtering was enabled.
Since the neighboring nodes of Router3 are Router2 and Leaf4, delete the old Router3 information and add the information of the new Router3 to each Router2 and Leaf4.

```
R2> macf del 001d129f35c50003          ← delete MAC address of old Router3
R2> macf allow 001d129f35c5fff3        ← allow MAC address of new Router3
```

```
L4> macf del 001d129f35c50003          ← delete MAC address of old Router3
L4> macf allow 001d129f35c5fff3        ← allow MAC address of new Router3
```

Wait approximately 2 minutes in this condition, and the new Router3 will connect to Router2, and Leaf4.

Run ping to check the connection.
If ping is run and there is response from Border1 to Leaf4, then the Router3 is successfully replaced.

```
BR1> ping 2001:db8::4                  ← run ping to Leaf4
```

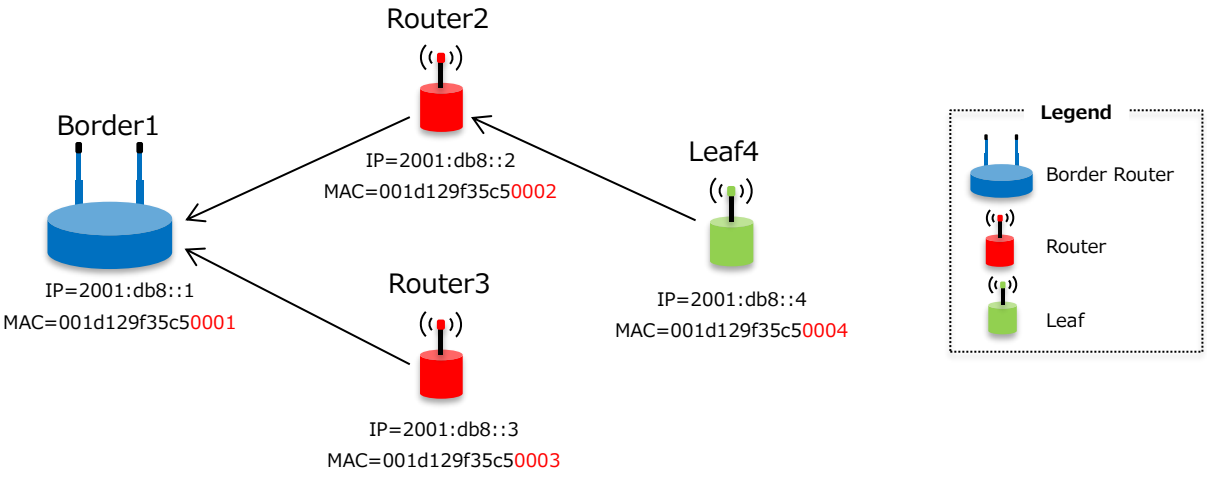
If ping is run and there is no response, review the settings on each node.

4. How to Verify the Routing

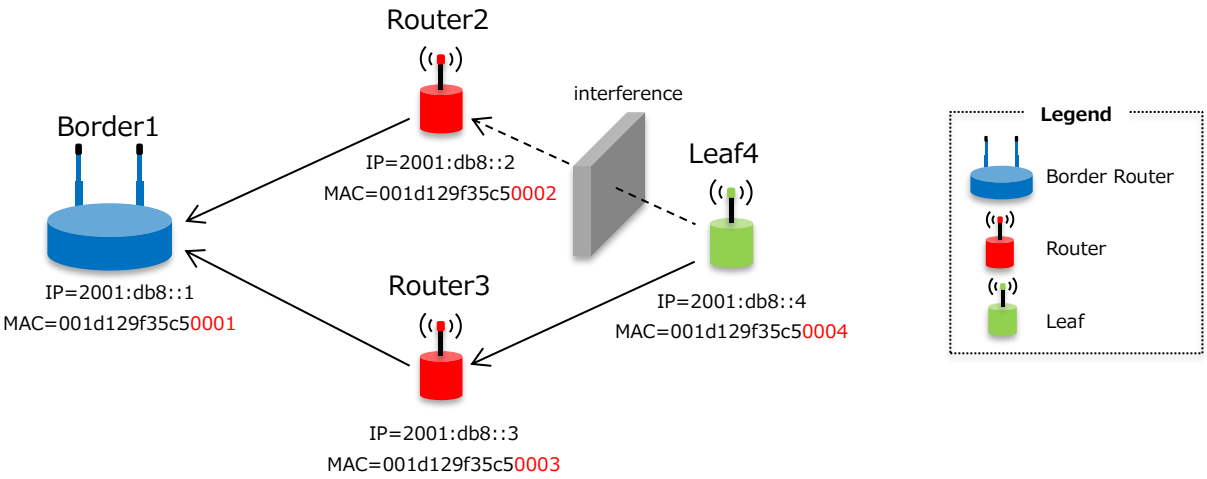
By using the "rplsr" command, the connection status of each node can be checked. (This command supports the Border only).

```
BR1> rplsr
rplsr - Routing links (3 in total)
rplsr -- 2001:db8::3 to 2001:db8::1 (lifetime: 7164 seconds)
rplsr -- 2001:db8::2 to 2001:db8::1 (lifetime: 7185 seconds)
rplsr -- 2001:db8::4 to 2001:db8::2 (lifetime: 7154 seconds)
```

The above indicates that Router3 is connected to Border1, Router2 is connected to Border1, and Leaf4 is connected to Router2. In other words, the connection is as follows.



For example, if the Router2 is blocked by some interference, and the radio wave condition deteriorates or stops due to failure, Leaf4 will change the connection destination from Router2 to Router3 by automatic routing. See the figure below.



At that time, the "rplsr" command results are shown below. Unlike the first figure above, Leaf4 is connected to the Router3.

```
BR1> rplsr
rplsr - Routing links (3 in total)
rplsr -- 2001:db8::3 to 2001:db8::1 (lifetime: 7151 seconds)
rplsr -- 2001:db8::2 to 2001:db8::1 (lifetime: 6512 seconds)
rplsr -- 2001:db8::4 to 2001:db8::3 (lifetime: 7177 seconds)
```

5. Remote Maintenance

Since FAN is a wide-ranging network, each node can be placed in a remote location. Normally, the location should be visited in order to check the status of a remote node. However, BP35C5 has a function called "remote command" in which a node can be remotely controlled as long as there is a connection with that node.
The "rmtcmd" command can send all commands that run locally. Therefore, the settings and sending/receiving of data can be confirmed as well as the status.

Example of status checking: Check the sending/receiving error rate of 2001:db8::17

```
> rmtcmd 2001:db8::17 mstat
rmtmsg <2001:db8::17>: mstat uptime 17min 46sec
rmtmsg <2001:db8::17>: mstat limit 204msec (max:256) in 20pkt (max:34 drop:0 cca:6) available 52233byte
rmtmsg <2001:db8::17>: mstat send total: 339 (ok:296 retry:7 err:0)
rmtmsg <2001:db8::17>: mstat recv total: 532 (ok:303 err:230)
>
```

Example of settings: Operate with MAC filter table of 2001:db8::10

Adding of MAC filter table

```
> rmtcmd 2001:db8::10 macf allow 001d129f35c502d2
>
```

Checking of MAC filter table

```
> rmtcmd 2001:db8::10 macf
rmtmsg <2001:db8::10>: macf default             ( deny  )
rmtmsg <2001:db8::10>: macf <001d129f35c501ca>  ( allow )
rmtmsg <2001:db8::10>: macf <001d129f35c502d2>  ( allow )
>
```

Example of data communication: Run ping from 2001:db8::6 to 2001:db8::13

```
> rmtcmd 2001:db8::6 ping 2001:db8::13
rmtmsg <2001:db8::6>: ping <2001:db8::13> (seq=1 sz=32bytes time=0.270sec) 1/1
rmtmsg <2001:db8::6>: 1 transmitted, 1 received, 0.0% loss (min=0.270/max=0.270/avr=0.270 sec)
>
```

6. Multicast Transmission

The multicast transmission can be used if you want to send to multiple grouped nodes at once.

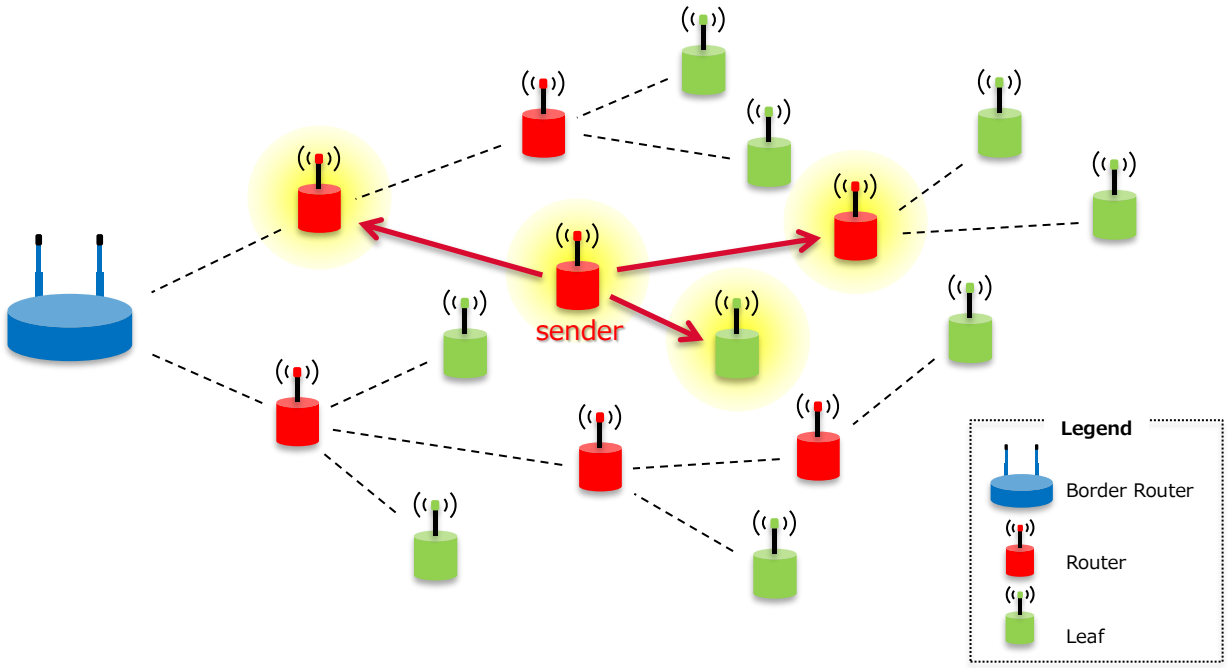
The multicast addresses supported by BP35C5 are the following.

Scope	IPv6 Address	Details
Link Local	ff02::1	All neighboring nodes (Border, Router, Leaf)
	ff02::2	All neighboring routers (Border, Router)
Realm Local	ff03::1	All nodes on the same network (Border, Router, Leaf)
	ff03::2	All routers on the same network (Border, Router)

Multicast transmission is only possible with UDP.

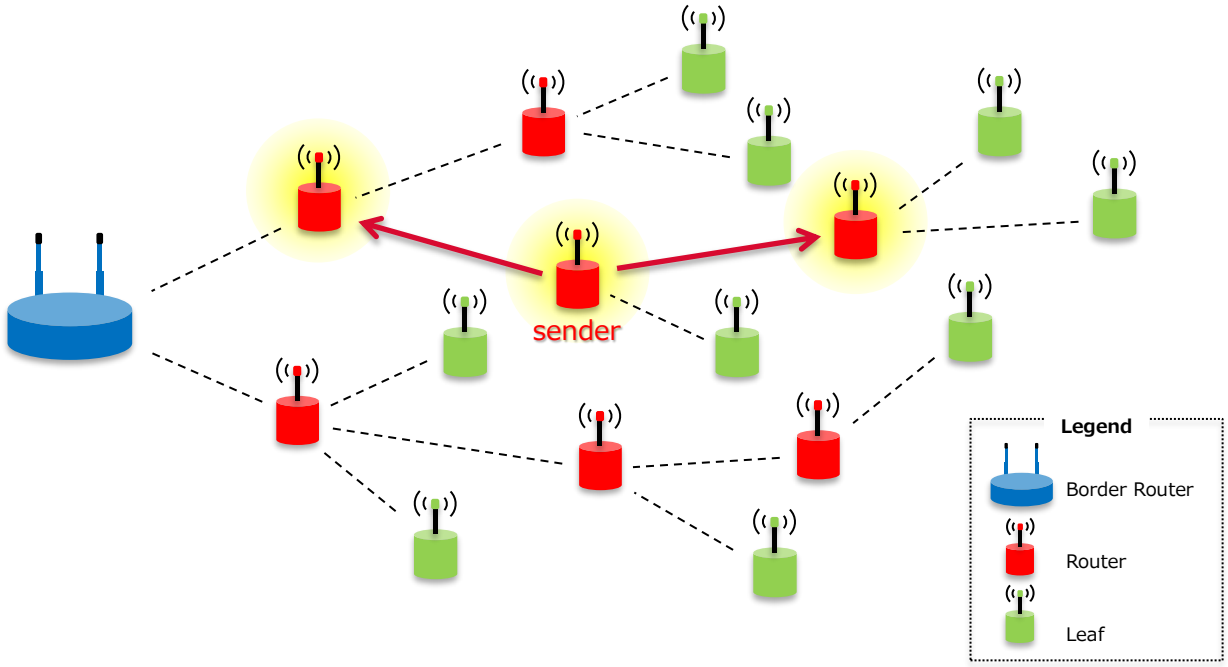
6.1. Multicasting to all neighboring nodes (ff02::1)

When sending to ff02::1, the data will be sent to all neighboring nodes following the path shown in the figure below.



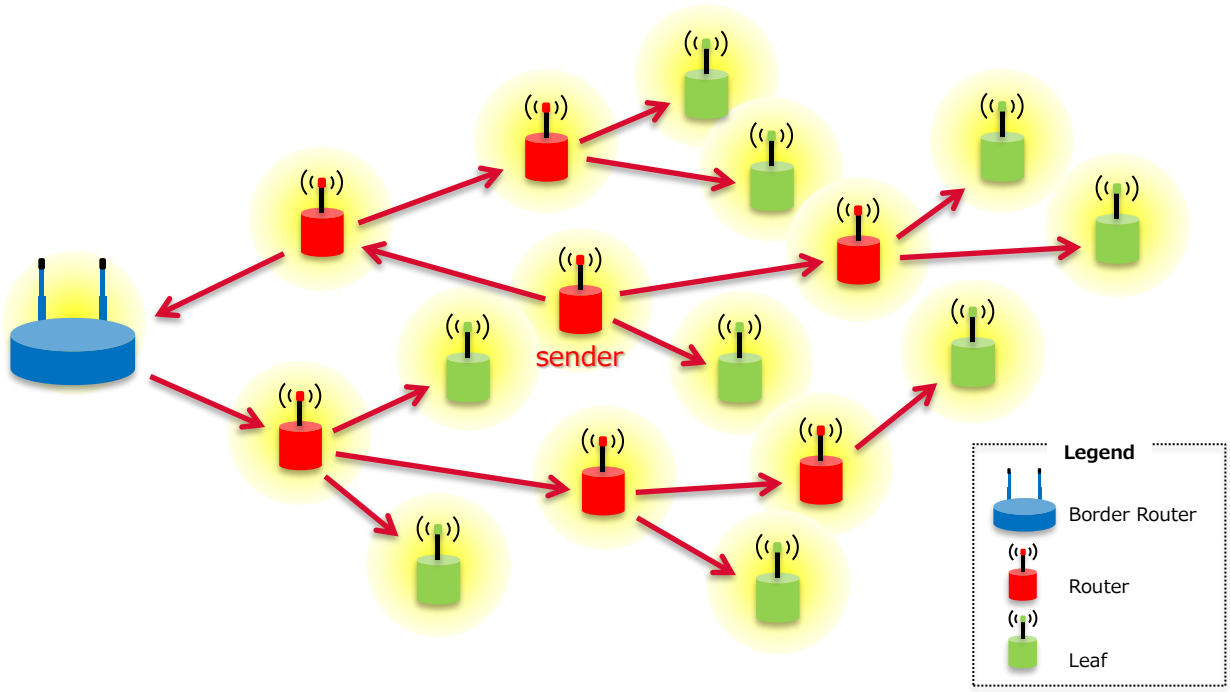
6.2. Multicasting to all neighboring routers (ff02::2)

When sending to ff02::2, the data will be sent only to all neighboring routers following the path shown in the figure below.



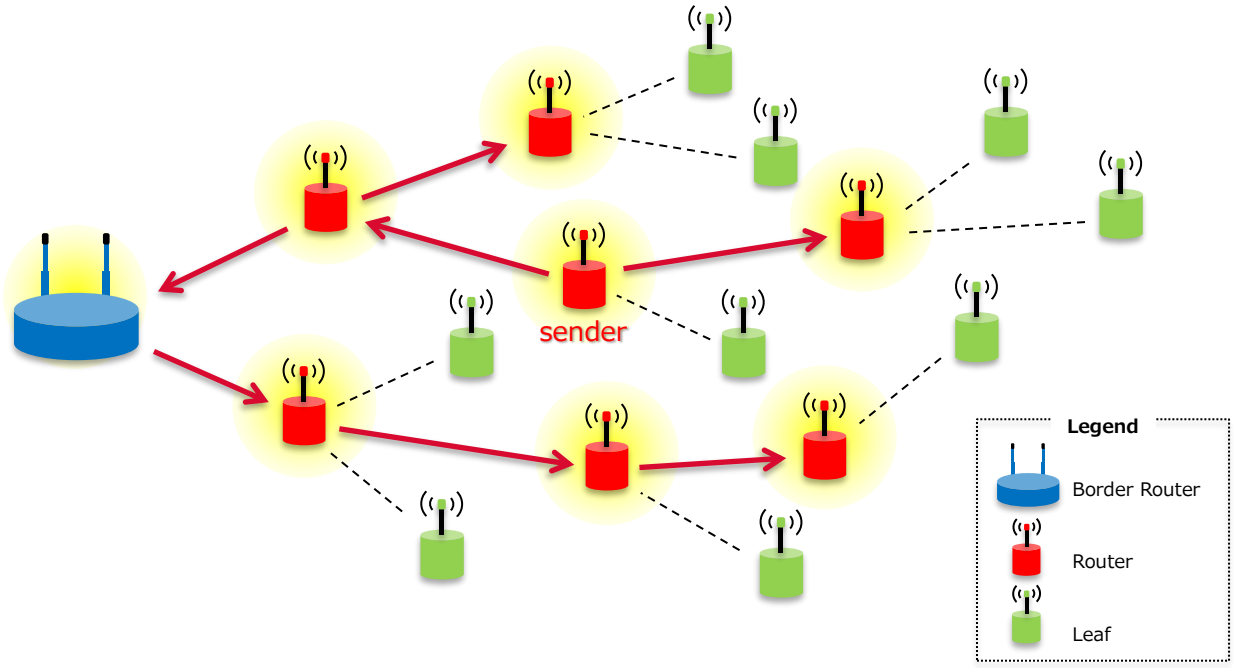
6.3. Multicasting to all nodes on the same network (ff03::1)

When sending to ff03::1, the data will be sent to all nodes following the path shown in the figure below.



6.4. Multicasting to all routers on the same network (ff03::2)

When sending to ff03::2, the data will be sent only to all routers following the path shown in the figure below.



7. Build Multiple Networks in the Same Area

When building multiple networks in the same area, they can be distinguished by network ID.

A network ID is a character string of 1 to 32 octets that can be assigned per network. The default is "Wi-SUN-FAN". The network ID can be set by entering the command below.

Example: Set the network ID to "Wi-SUN-FAN 0001" and save. Then, reset it.

```
> netname "Wi-SUN-FAN 0001"
netname Wi-SUN-FAN (prm):Wi-SUN-FAN 0001
> save
save parameter is saved
> reset
```

For each network you want to distinguish, it can be treated as an independent network by setting a different network ID.

8. How to Use a Non-default Port for UDP/TCP

After firmware booting, the following ports are available without any setting.

Protocol	Application	Port No.	Remarks
UDP	For UDP binary code communication	3610	Default port used in udps command
	For UDP text character string communication	20171	Default port used in udpst command
TCP	For TCP communication	3610	Default port used in tcps command

These are called default ports. When a destination port number is omitted in udps, udpst, and tcps, these port numbers are applied.

In this product, the communication port number can also be used by using udpopts and tcpopts commands in addition to the above.
Here are some examples:

```
> udpopts listen_port 50000          ← open port 50000 for UDP binary code communication
> udpopts listen_port_text 51000     ← open port 51000 for UDP text character string communication
> tcpopts listen_port 60000          ← open port 60000 for TCP communication
```

To send the data to this port after setting the port, enter the following.

```
> udps 2001:db8::1 50000 0123456789  ← send binary code by UDP to port 50000
> udpst 2001:db8::1 51000 "hello"    ← send text character string by UDP to port 51000
> tcps 2001:db8::1 60000 abcdef      ← send data byTCP to port 60000
```

The following appears on the receiver.

```
> udpr <2001:db8::2> 0123456789      ← communication result by udps
> udprt <2001:db8::2> "hello"        ← communication result by udpst
> tcpr <2001:db8::2> abcdef          ← communication result by tcps
```

Although the received port number is not known by this, there is a way to display the port number.

If you want to display the port number on the receiver, specify the following.

```
> udpopts disp_port 1                ← UDP settings that display the port numbers when receiving
> tcpopts disp_port 1                ← TCP settings that display the port numbers when receiving
```

After setting the port number to be displayed, the following is shown on the receiver.

```
> udpr <2001:db8::2> (50000) 0123456789      ← communication result by udps (receive port number display)
> udprt <2001:db8::2> (51000) "hello"        ← communication result by udpst (receive port number display)
> tcpr <2001:db8::2> (60000) abcdef          ← communication result by tcps (receive port number display)
```

All open ports except for the default port can be closed (only particular ports cannot be closed) by designating -1 to port number as follows.

```
> udpopts listen_port -1                     ← close all UDP binary code communication ports
> udpopts listen_port_text -1                ← close all udp text character string communication ports
> tcpopts listen_port -1                     ← close all TCP communication ports
```

Note:

- The number of ports that can be used simultaneously is up to four ports for each udp binary code communication ports, UDP text string communication ports, and TCP communication ports. Those four ports also include the default port.

9. Notification of Transmission Completion

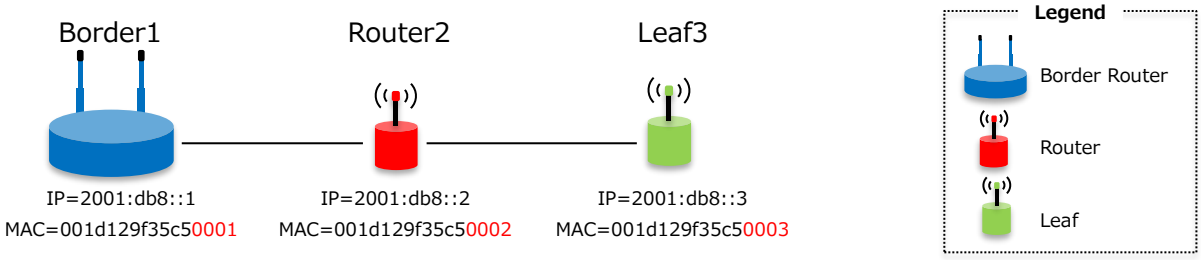
Set the following to receive a notification of complete transmission when sending by TCP or UDP.

```
> tcpopts send_done on      ← Enable TCP notification of complete transmission

> udpopts send_done on      ← Enable UDP notification of complete transmission
```

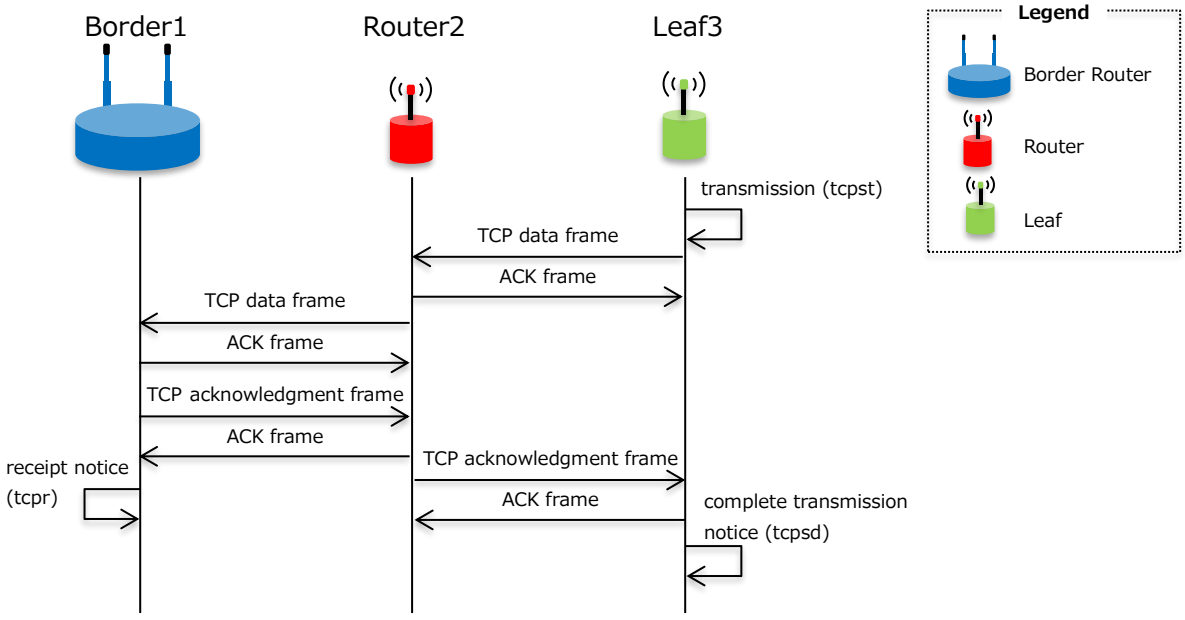
With the above settings, the notification of complete transmission will be issued after sending the data as follows.

```
> tcps 2001:db8::1 abcdef
tcpsd <2001:db8::1>         ← TCP notification of complete transmission

> udps 2001:db8::1 0123456789
udpsd <2001:db8::1>         ← UDP notification of complete transmission
```

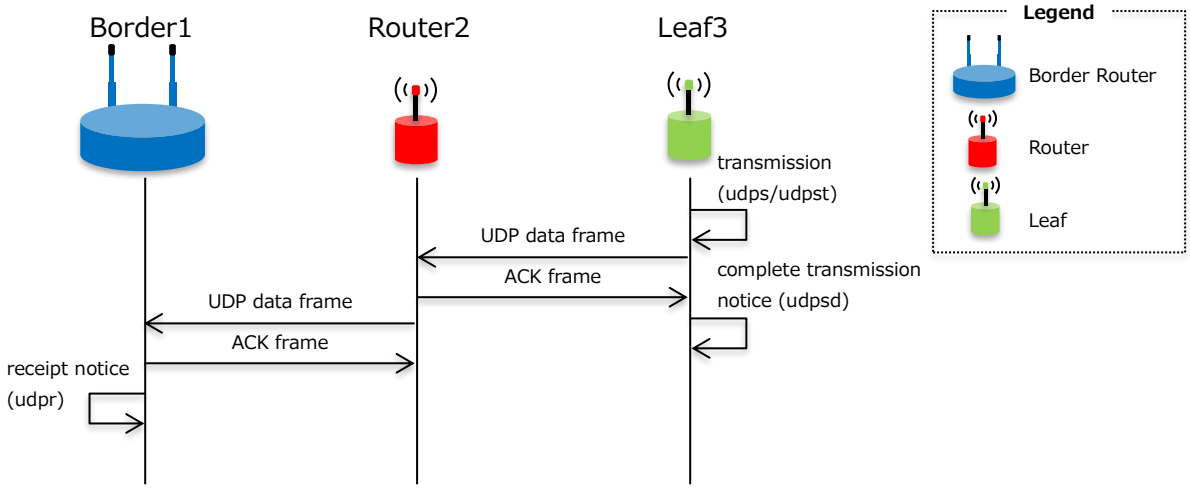
The conditions for issuing the notification of complete transmission are different for TCP and UDP.
For example, consider the following network configuration.



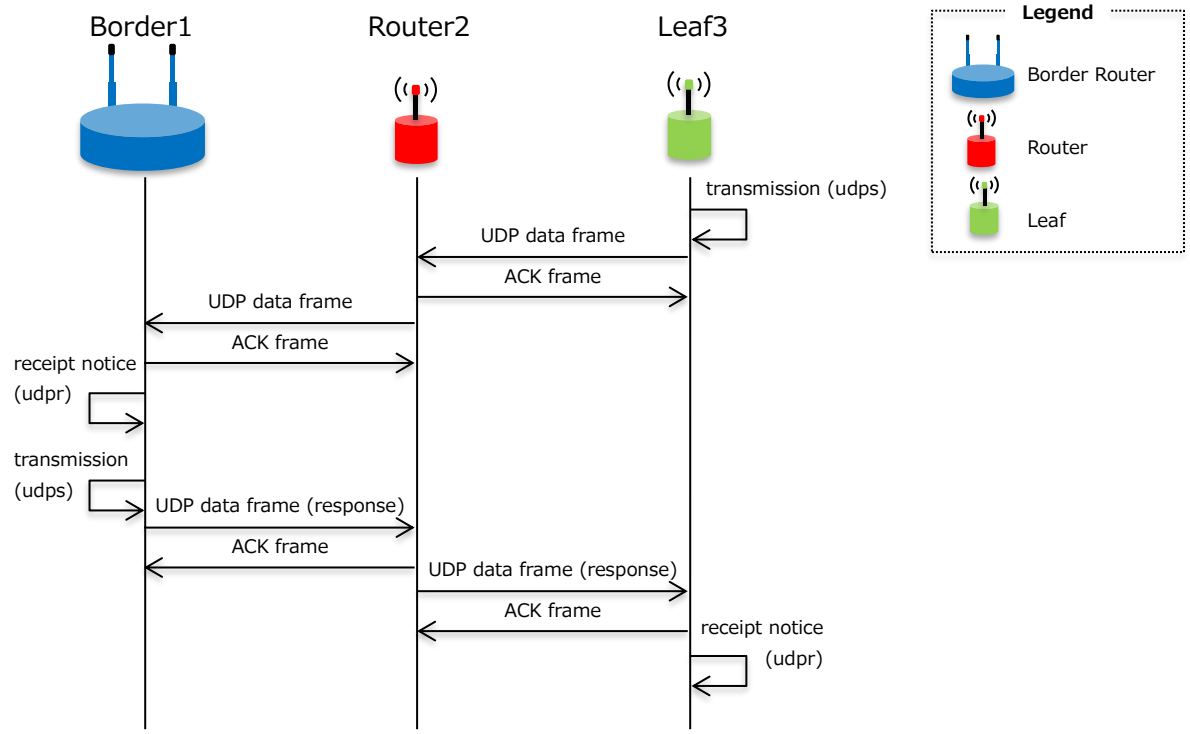
When the data is sent from Leaf3 to Border1 using TCP, a notification of transmission completion (tcpsd) is issued once the data is confirmed to have reached the destination Border1.



On the other hand, UDP issues a notification of transmission completion (udpsd) when it is confirmed that ACK has returned from the neighboring Router2, not when it reaches the Border1. For this reason, it is not possible to check that the Border1 has been reached by the notification of transmission completion only.

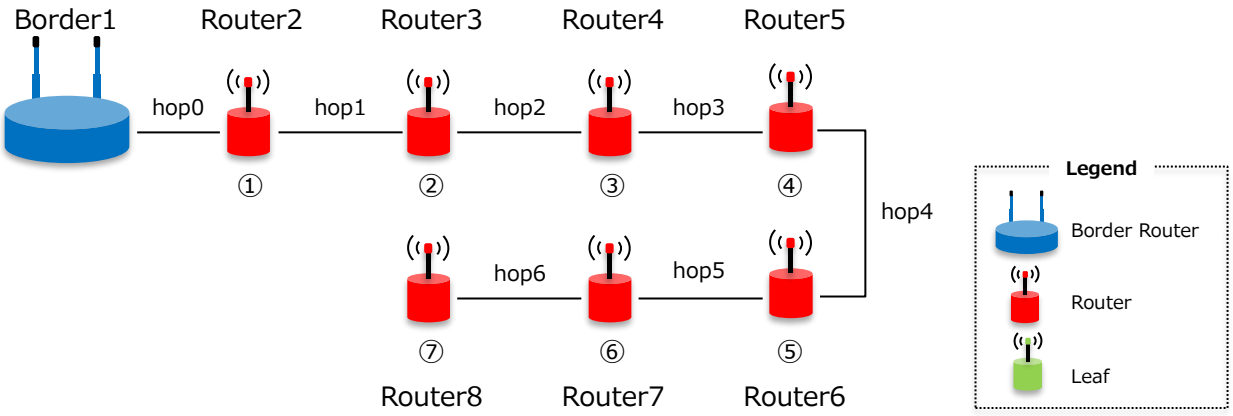


If it is necessary to confirm that the data has reached in Border1 by UDP communication, you have to implement a process in which the response frame will return from Border1 as shown below.



10. Connection Time

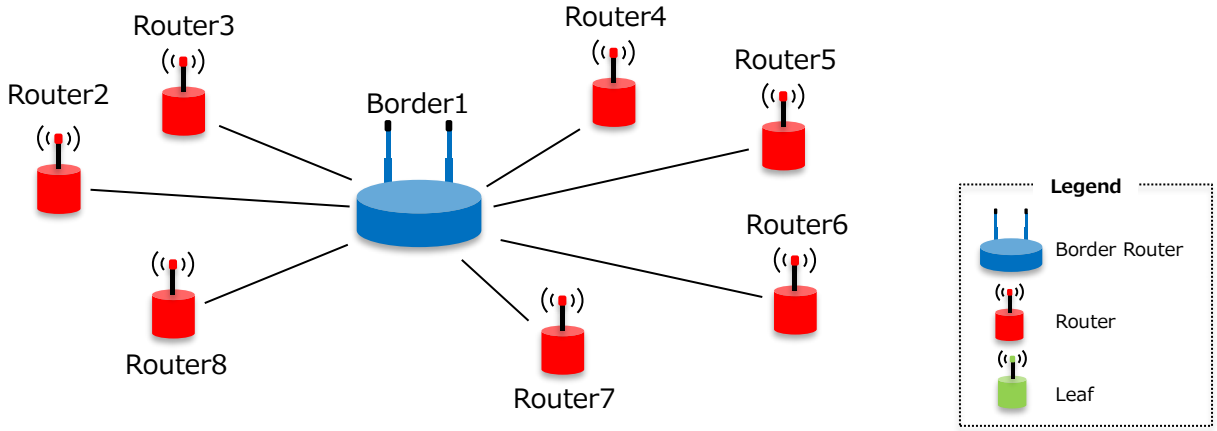
This chapter describes the time required for Router to connect to Border.
When considering the time it takes for the entire network to connect, the network topology has a big impact.
If the network topology is serial, the routers are connected in the order ①→②→③→④→⑤→⑥→⑦ as shown in the diagram below.



In the case of a serial topology, the node connection time is as shown in the table below (example of 100 actual measured samples).

Time(sec)	hop0	hop1	hop2	hop3	hop4	hop5	hop6
Maximum	58.1	72.2	61.3	100.5	82.7	126.8	126.1
Average	37.9	38.9	40.4	44.7	43.7	48.1	47.7
Minimum	25.2	29.2	31.3	33.3	32.4	35.8	36.7

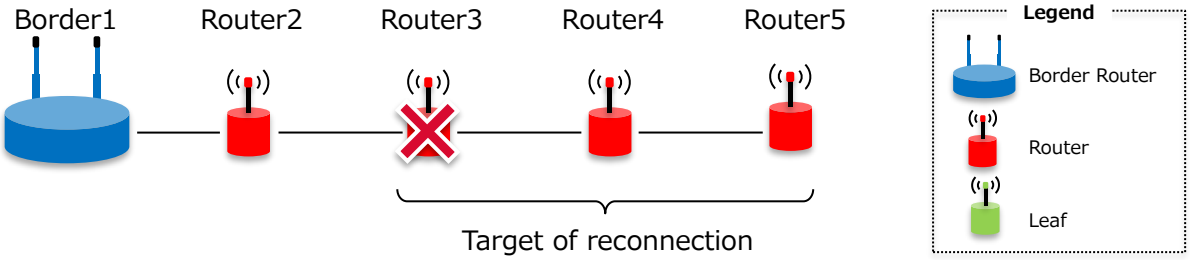
When the network topology is star, the connection order is not fixed and each router connects one after the other at the hop0 time shown in the table above. In the case of a serial topology, it was necessary to wait for the parent router to connect, but in the case of a star topology, it connects directly to the border, so the network connection is completed in a shorter time than in a serial topology.



The tree topology is a combination of the star and the serial topology, and the connection time is largely determined by the number of nodes (depth) from the border to the farthest node.
The mesh topology is an evolution of the tree topology and changes dynamically depending on the radio wave conditions.

It also explains the concept of connection time when a failure occurs.

For example, if Router3 in the figure below goes down, Router3 to Router5 will be unconnected.

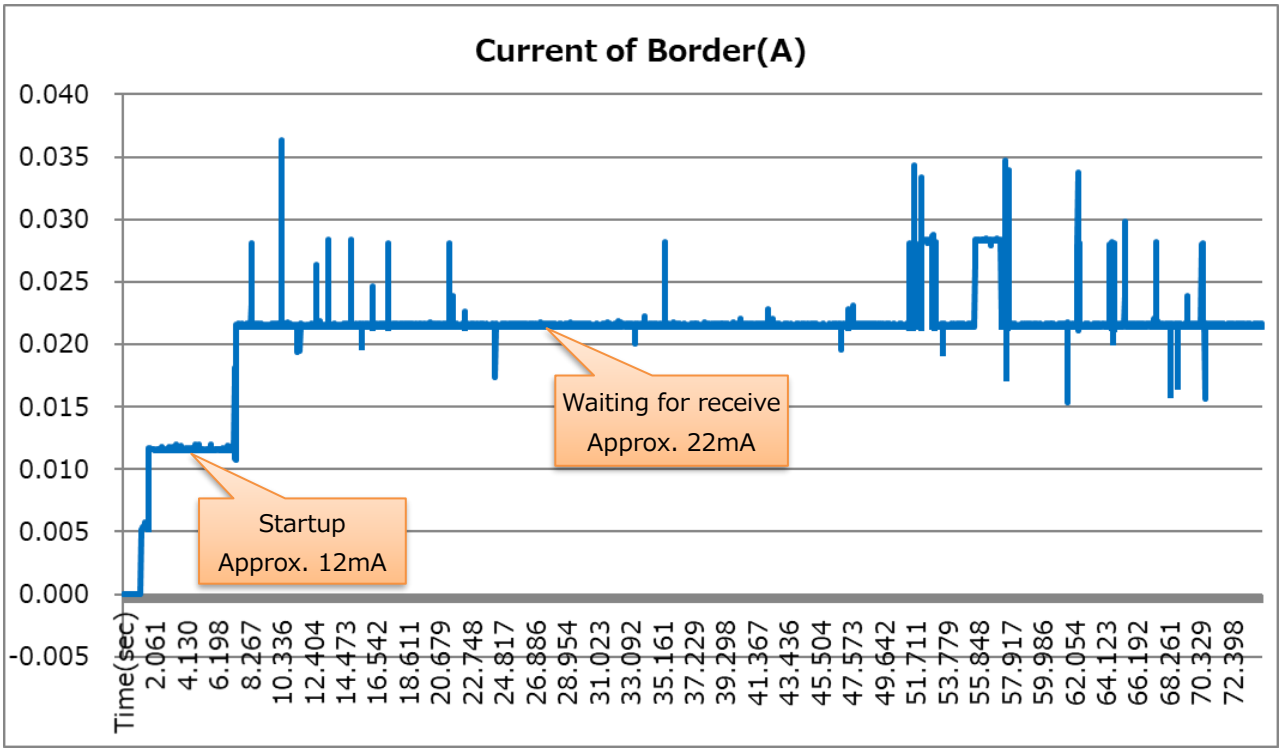


When Router3 goes down, only Router3 is disconnected, and it seems that Router4 and Router5 are still connected, but after Router3, it will not be connected to Border, so Router3 subsequent items will be reconnected. Therefore, the reconnection time is the cumulative connection time of Router3 to Router5.

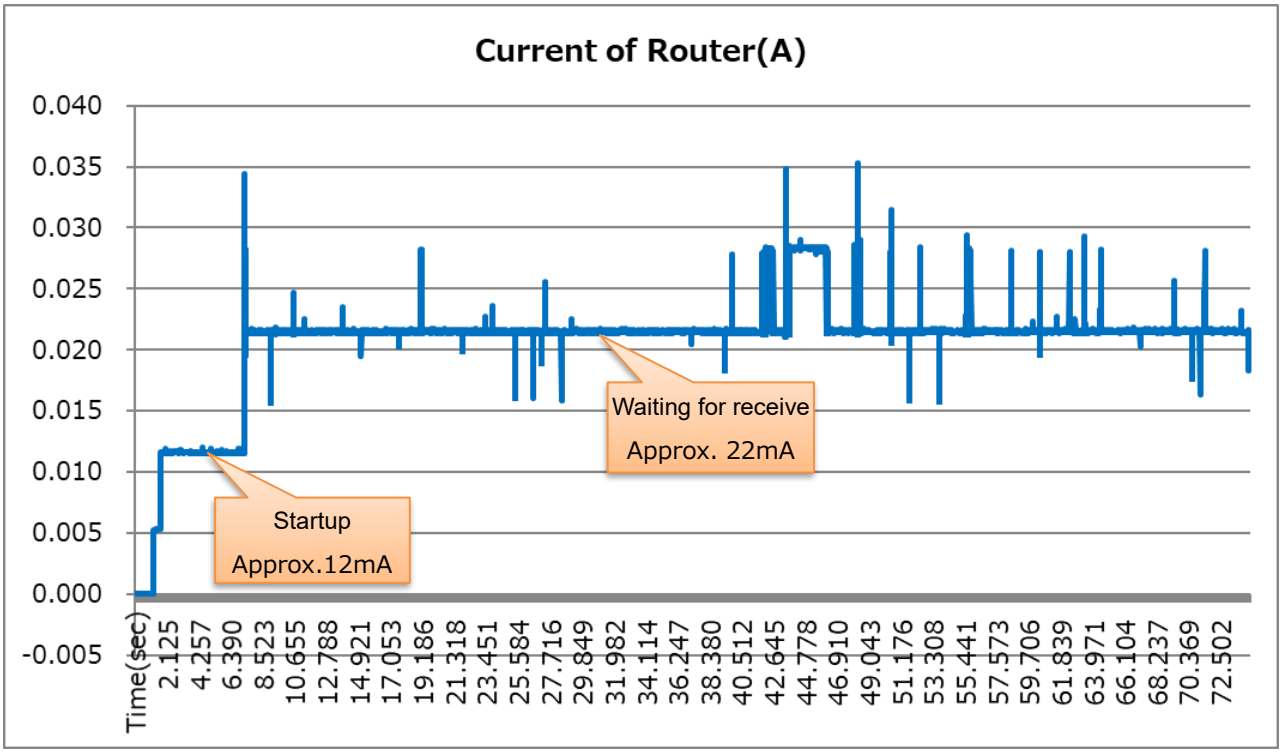
11. Power Consumption (for reference)

This chapter describes the power consumption of Border, Router, and Leaf.
The FAN 1.0 standard does not specify a power saving mode, so Border, Router, and Leaf all wake up without sleeping.

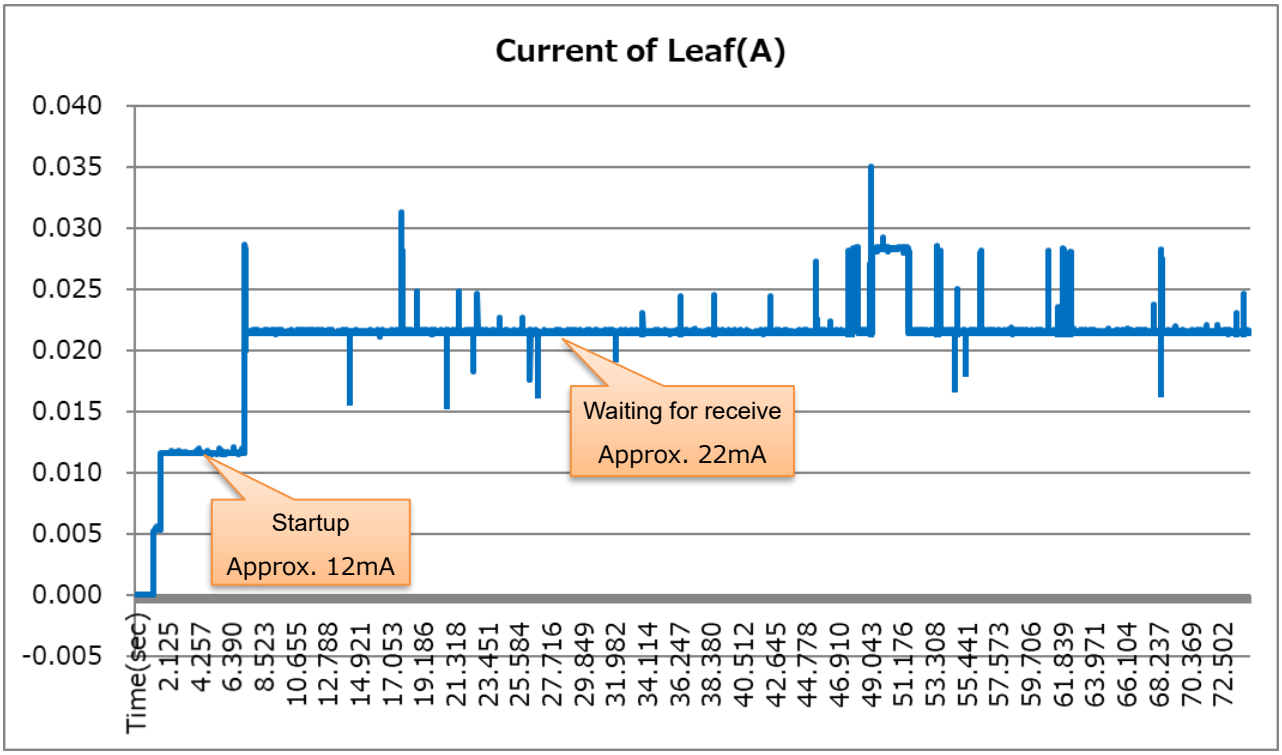
Example of Border current waveform from startup to connection.
(EW-WSN-FAN 1.0.54, Rate 150kbps, CH59, Region:JP)



Example of Router current waveform from startup to connection.
(EW-WSN-FAN 1.0.54, Rate 150kbps, CH59, Region:JP)



Example of Leaf current waveform from startup to connection.
(EW-WSN-FAN 1.0.54, Rate 150kbps, CH59, Region:JP)

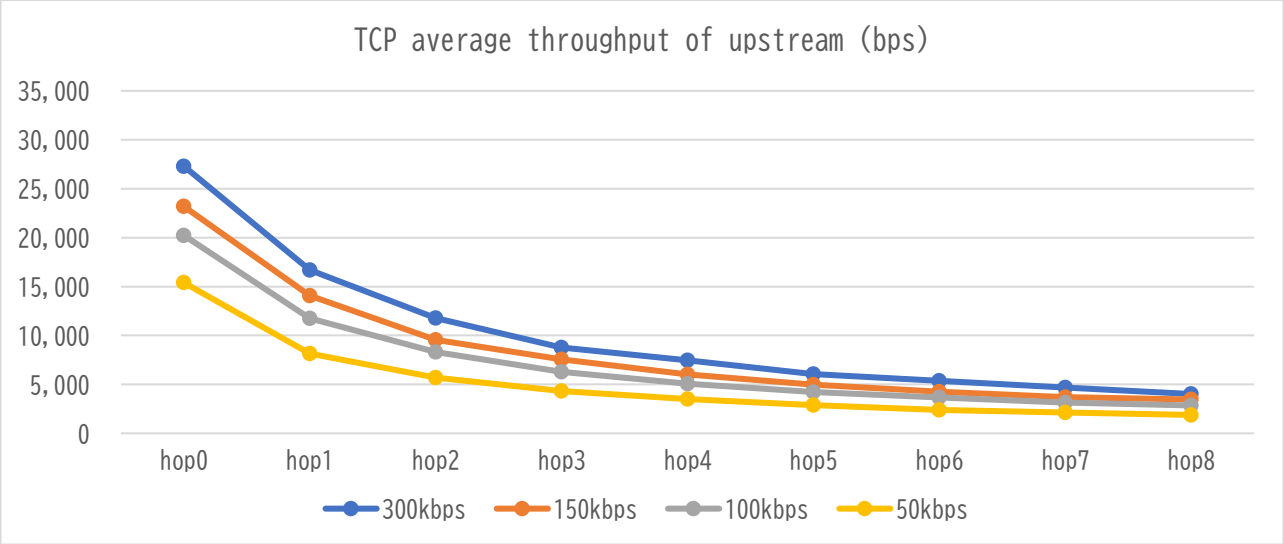


Note: The current consumption during wireless transmission (20 mW output) is 40 mA (typ.).
Note: In the waveform shown above, the current consumption immediately before and after the transmit state is not represented accurately due to the resolution limit of the measuring equipment. Please understand that this figure is intended to show an overview of the entire operation from startup to connection.

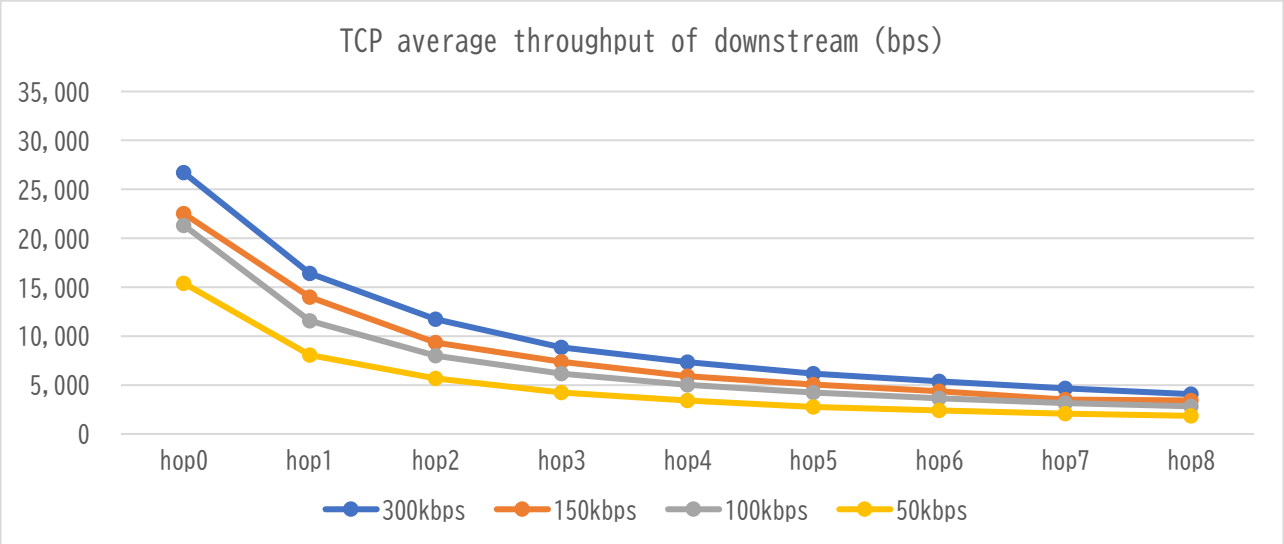
12. Throughput and latency (for reference)

The "throughput" in this document indicates how many bits (bps) can be transmitted from the source node to the destination node per second. The "latency" indicates how many milliseconds after the specified size of data sent from the source node arrives at the destination node. The latency is calculated from the throughput result.

12.1. TCP average throughput

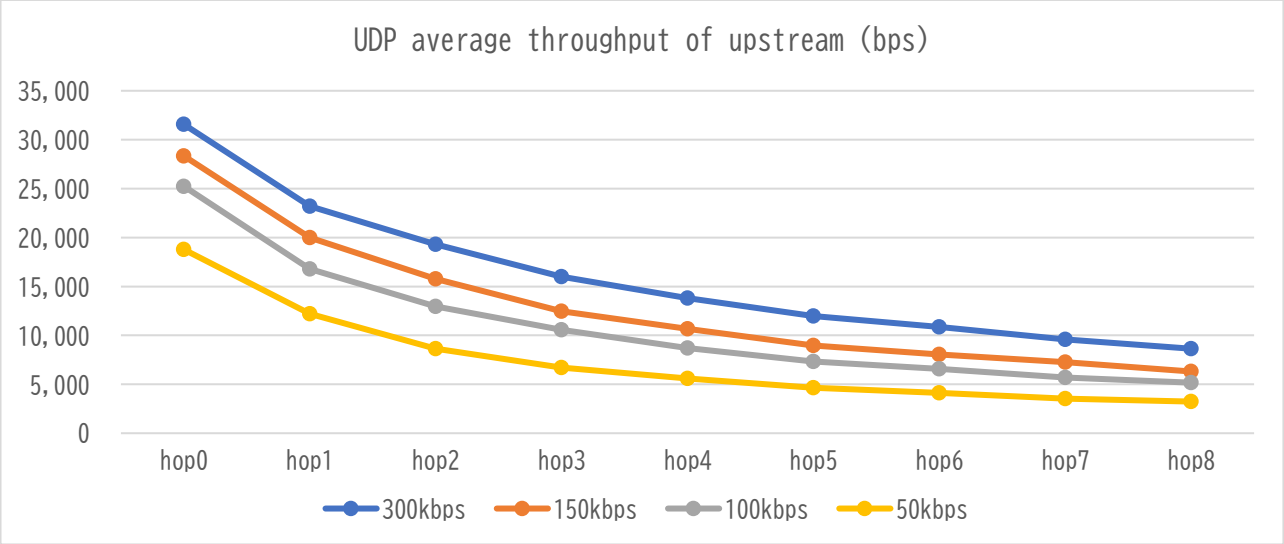


TCP Up	hop0	hop1	hop2	hop3	hop4	hop5	hop6	hop7	hop8
300kbps	27, 299	16, 688	11, 786	8, 762	7, 465	6, 044	5, 360	4, 679	4, 019
150kbps	23, 187	14, 082	9, 564	7, 556	6, 019	4, 981	4, 240	3, 683	3, 456
100kbps	20, 226	11, 731	8, 310	6, 269	5, 084	4, 223	3, 663	3, 154	2, 849
50kbps	15, 395	8, 132	5, 699	4, 317	3, 496	2, 872	2, 381	2, 132	1, 879

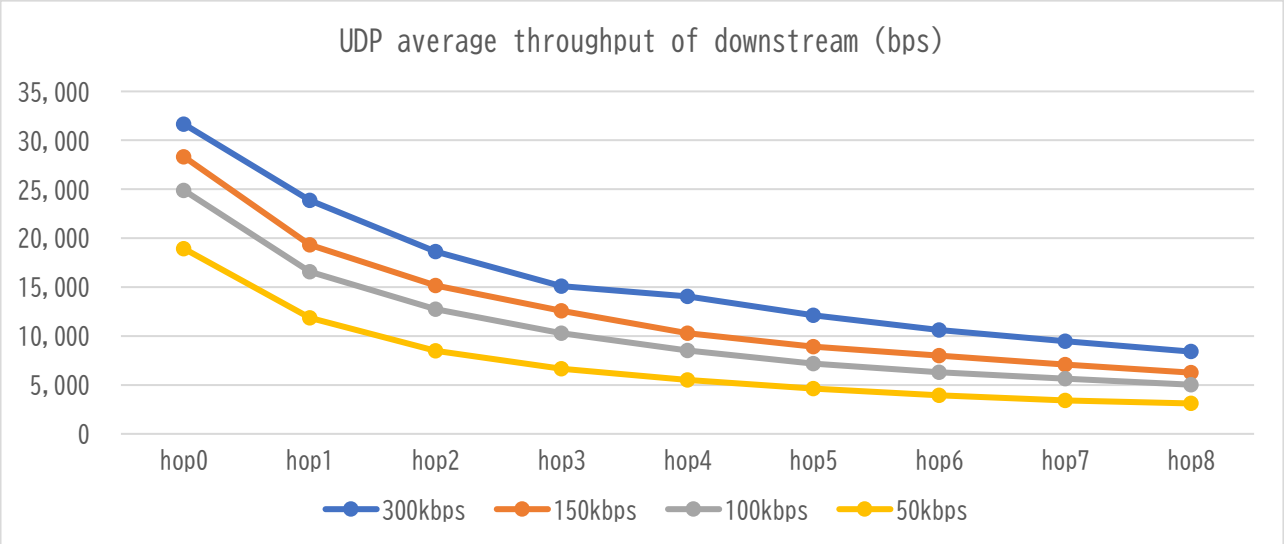


TCP Down	hop0	hop1	hop2	hop3	hop4	hop5	hop6	hop7	hop8
300kbps	26, 704	16, 399	11, 727	8, 838	7, 338	6, 168	5, 383	4, 661	4, 071
150kbps	22, 511	13, 977	9, 352	7, 379	5, 897	5, 039	4, 365	3, 500	3, 424
100kbps	21, 317	11, 571	7, 995	6, 161	5, 022	4, 218	3, 658	3, 150	2, 826
50kbps	15, 401	8, 063	5, 660	4, 243	3, 411	2, 768	2, 396	2, 082	1, 851

12.2. UDP average throughput

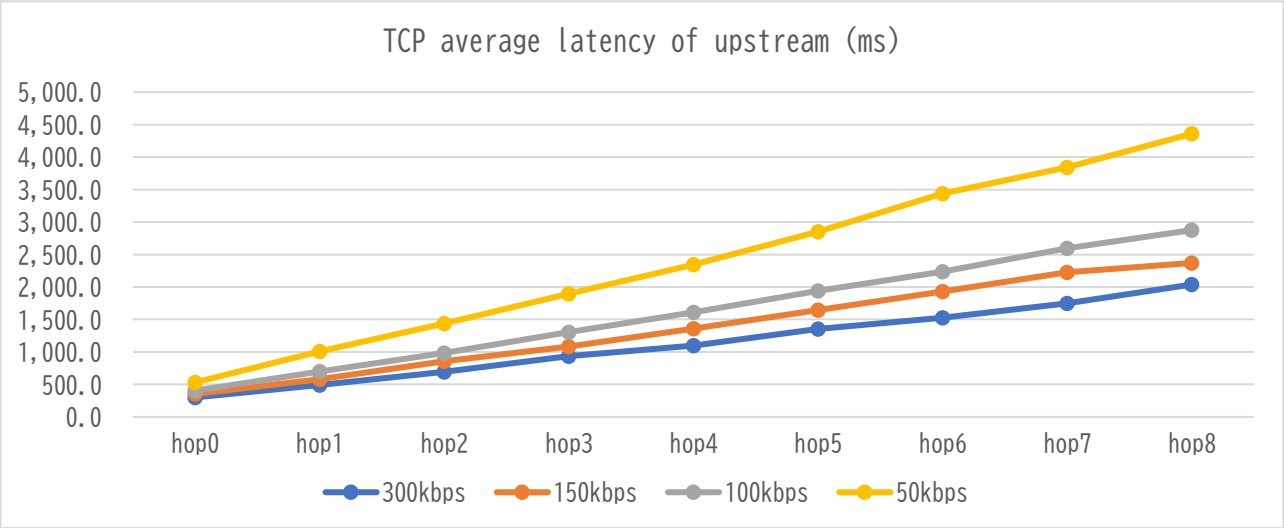


UDP Up	hop0	hop1	hop2	hop3	hop4	hop5	hop6	hop7	hop8
300kbps	31, 561	23, 212	19, 294	16, 013	13, 819	11, 989	10, 870	9, 579	8, 636
150kbps	28, 336	19, 982	15, 776	12, 452	10, 668	8, 975	8, 064	7, 248	6, 309
100kbps	25, 237	16, 793	12, 962	10, 566	8, 703	7, 331	6, 590	5, 696	5, 167
50kbps	18, 776	12, 189	8, 639	6, 723	5, 581	4, 655	4, 130	3, 547	3, 232

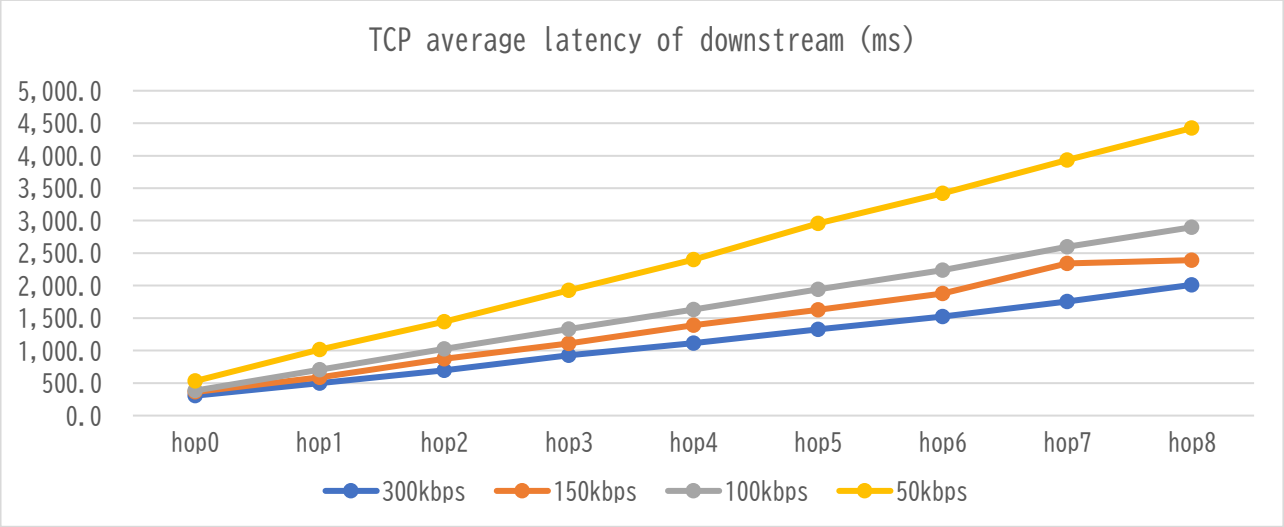


UDP Down	hop0	hop1	hop2	hop3	hop4	hop5	hop6	hop7	hop8
300kbps	31, 659	23, 875	18, 644	15, 090	14, 057	12, 109	10, 623	9, 463	8, 407
150kbps	28, 323	19, 310	15, 172	12, 569	10, 300	8, 924	7, 986	7, 067	6, 257
100kbps	24, 890	16, 560	12, 747	10, 272	8, 506	7, 178	6, 299	5, 643	5, 024
50kbps	18, 936	11, 843	8, 476	6, 640	5, 500	4, 643	3, 931	3, 403	3, 108

12.3. TCP average latency

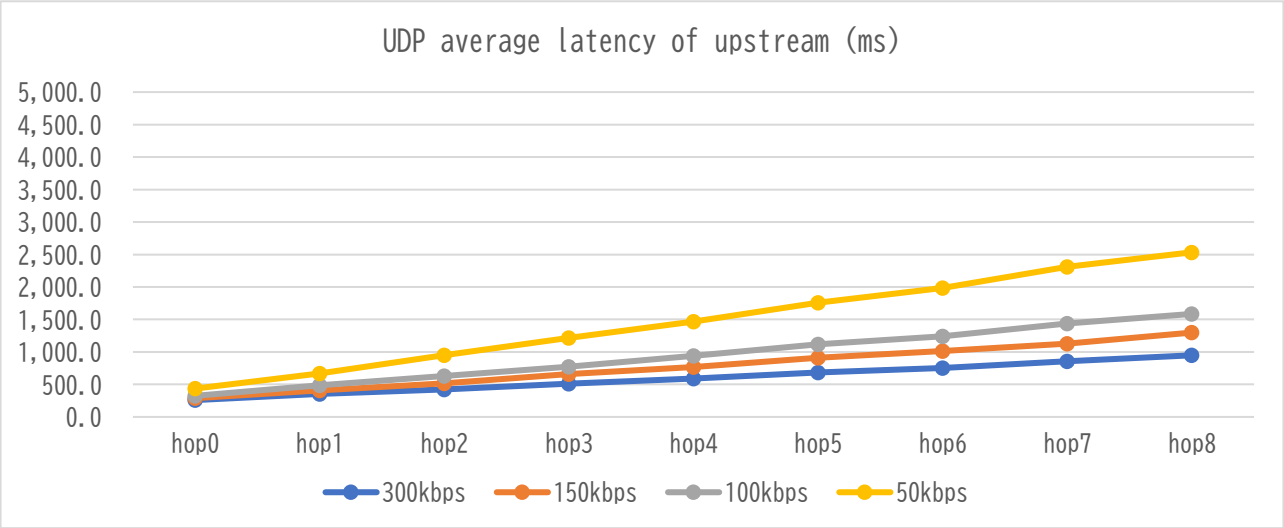


TCP Up	hop0	hop1	hop2	hop3	hop4	hop5	hop6	hop7	hop8
300kbps	300.1	490.9	695.1	934.9	1,097.4	1,355.4	1,528.3	1,750.8	2,038.4
150kbps	353.3	581.7	856.6	1,084.1	1,361.0	1,644.6	1,931.9	2,224.4	2,370.1
100kbps	405.0	698.3	985.8	1,306.7	1,611.2	1,939.6	2,236.5	2,597.2	2,875.5
50kbps	532.1	1,007.4	1,437.6	1,897.7	2,343.1	2,852.1	3,440.1	3,842.5	4,358.8

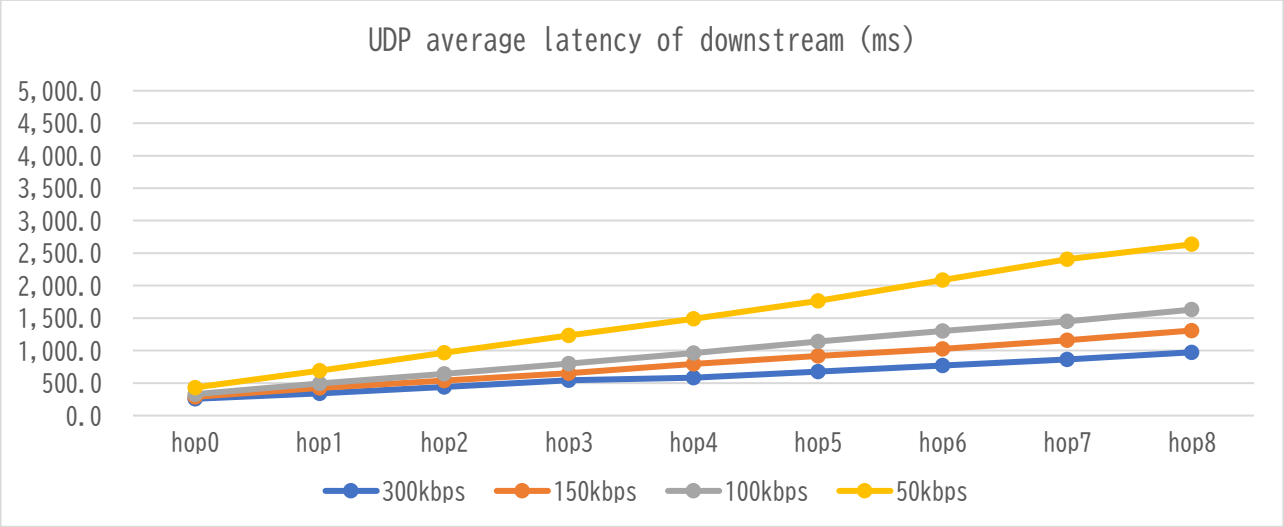


TCP Down	hop0	hop1	hop2	hop3	hop4	hop5	hop6	hop7	hop8
300kbps	306.8	499.5	698.6	926.9	1,116.4	1,328.1	1,521.7	1,757.5	2,012.4
150kbps	363.9	586.1	876.0	1,110.2	1,389.2	1,625.7	1,876.8	2,340.9	2,392.2
100kbps	384.3	708.0	1,024.7	1,329.6	1,631.2	1,941.9	2,239.5	2,600.7	2,898.3
50kbps	531.9	1,016.0	1,447.3	1,930.5	2,401.4	2,959.5	3,419.2	3,934.2	4,425.1

12.4. UDP average latency



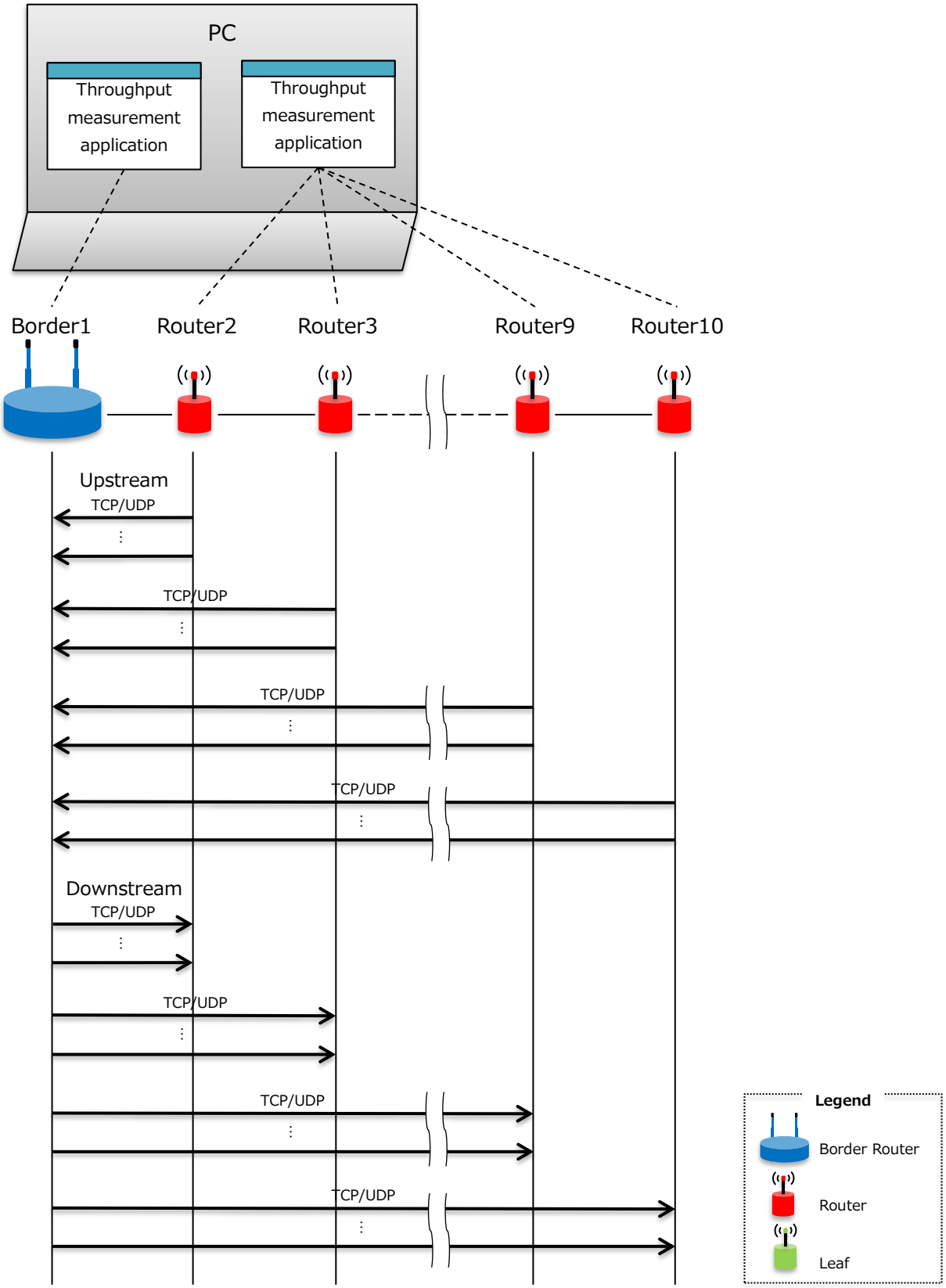
UDP Up	hop0	hop1	hop2	hop3	hop4	hop5	hop6	hop7	hop8
300kbps	259.6	352.9	424.6	511.6	592.8	683.3	753.6	855.2	948.6
150kbps	289.1	410.0	519.3	657.9	767.9	912.8	1,015.8	1,130.2	1,298.5
100kbps	324.6	487.8	632.0	775.3	941.3	1,117.4	1,243.0	1,438.1	1,585.4
50kbps	436.3	672.1	948.3	1,218.5	1,467.9	1,759.7	1,983.7	2,309.7	2,534.4



UDP Down	hop0	hop1	hop2	hop3	hop4	hop5	hop6	hop7	hop8
300kbps	258.8	343.1	439.4	542.9	582.8	676.5	771.2	865.7	974.4
150kbps	289.2	424.2	539.9	651.8	795.3	918.0	1,025.8	1,159.2	1,309.3
100kbps	329.1	494.7	642.7	797.5	963.1	1,141.3	1,300.5	1,451.7	1,630.4
50kbps	432.6	691.7	966.5	1,233.7	1,489.4	1,764.4	2,084.1	2,407.3	2,635.8

12.5. Measuring method

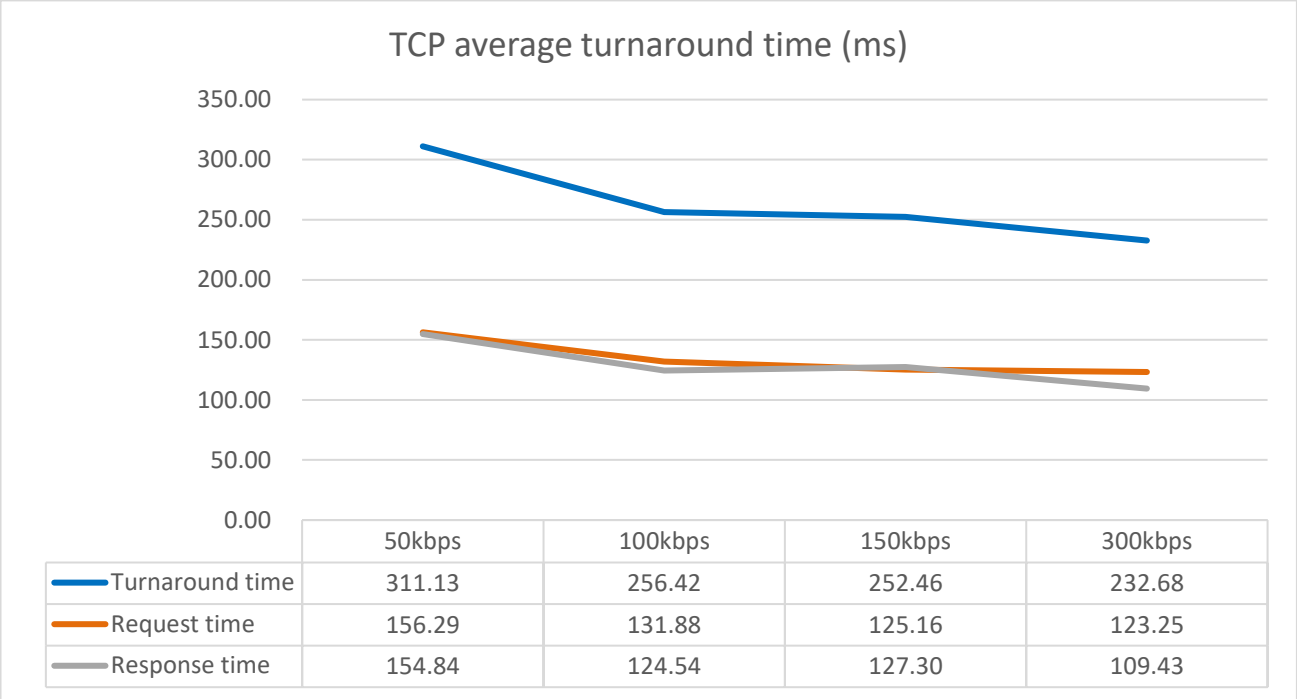
Build a 8-hop serial network (Border and 9 Routers), use the throughput measurement application to send data 1,024 octets of payload data in both the upstream and downstream directions using TCP and UDP, and measured the throughput between two points 100 times each.



13. Turnaround time (for reference)

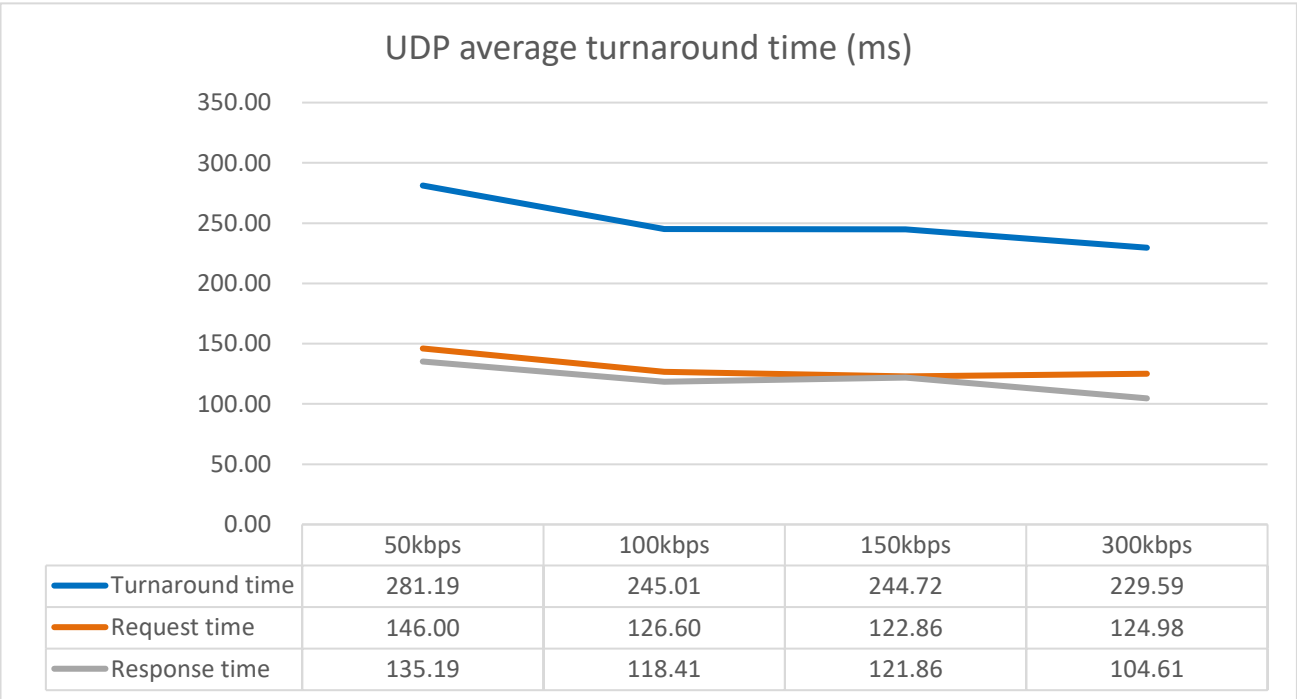
The turnaround time in this document is the time is takes for the requester to send the request and return a response. This request time indicates the time from the request source to the destination, and the response time indicates the time from the destination to the request source.

13.1. TCP average turnaround time



	50kbps	100kbps	150kbps	300kbps
Turnaround time	311.13	256.42	252.46	232.68
Request time	156.29	131.88	125.16	123.25
Response time	154.84	124.54	127.30	109.43

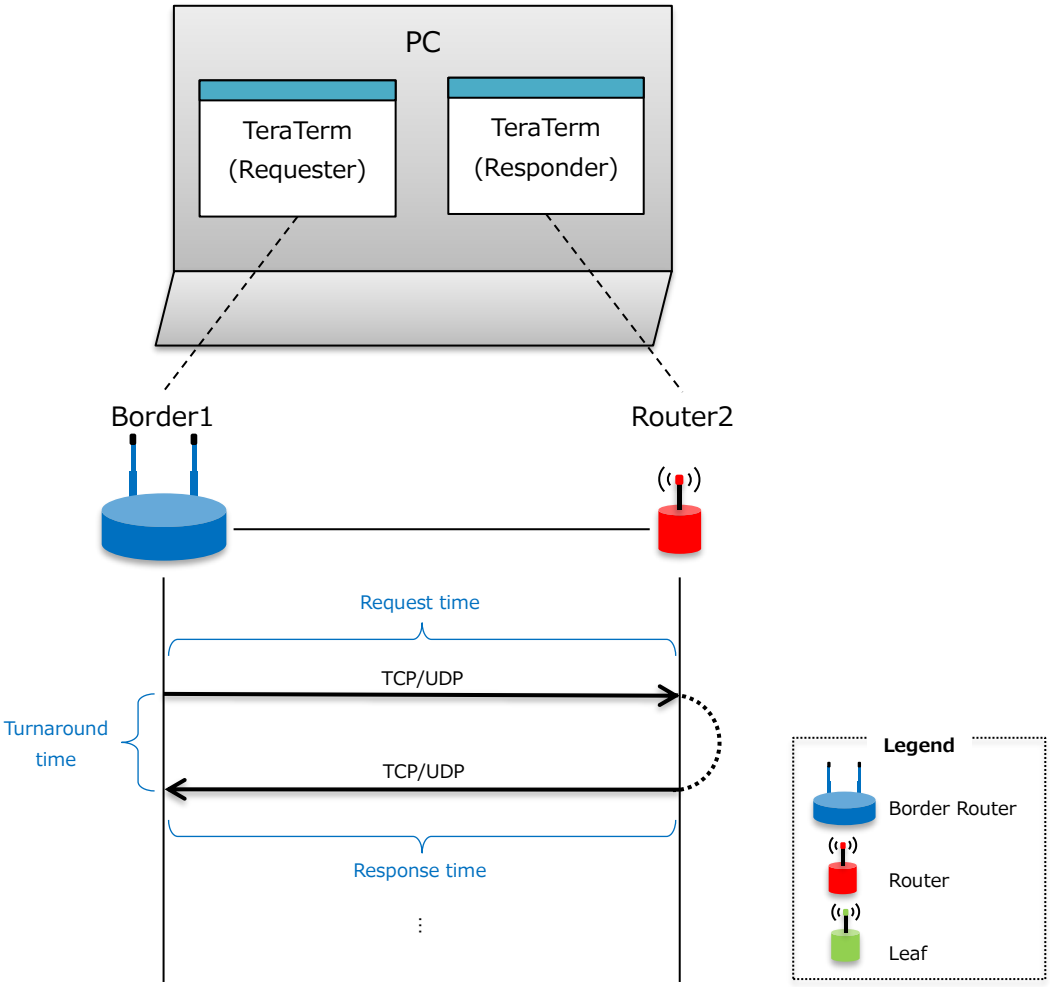
13.2. UDP average turnaround time



	50kbps	100kbps	150kbps	300kbps
Turnaround time	281.19	245.01	244.72	229.59
Request time	146.00	126.60	122.86	124.98
Response time	135.19	118.41	121.86	104.61

13.3. Measuring method

Build a network that connects Border and Router 1:1 and used the TeraTerm macro to send a request packet from Border and measured the time it takes for Router to return a response packet (turnaround time) 100 times. The payload size of the request packet and the response packet is 32 octets each.



14. Maximum number of connections

This chapter describes the specifications for the maximum number of connection.
The specifications of the number of nodes that BP35C5 itself[1] can manage are as follows:

[Target firmware version : 1.0.56.60]

Item	Spec.
Maximum number of connection per Border Router	16 nodes
Maximum number of connection per Router	15 nodes
Maximum number of hops	16 hops

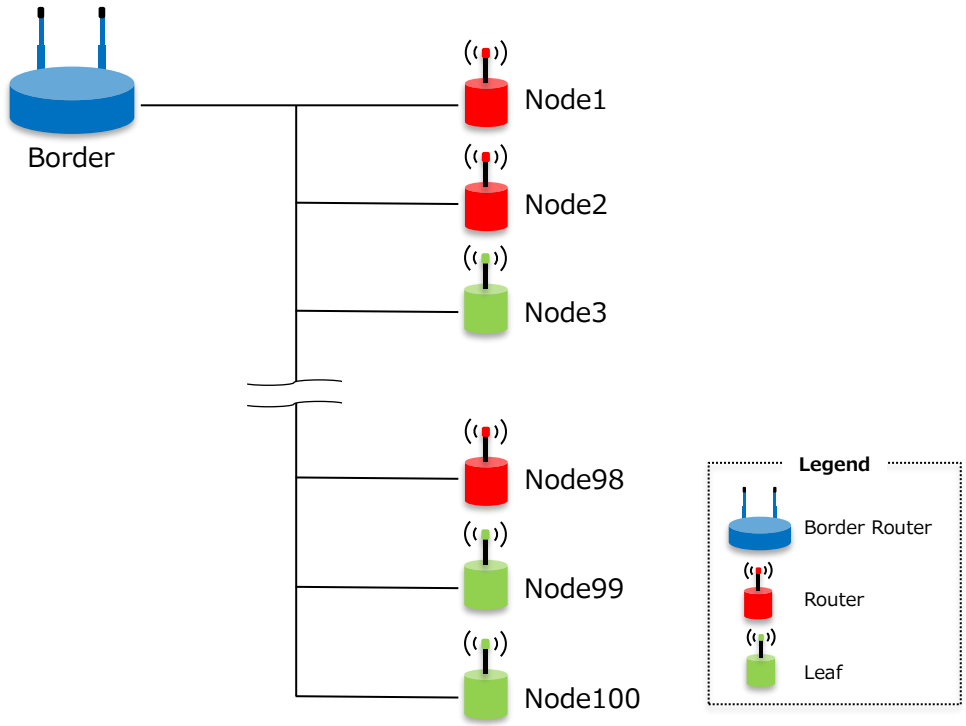
[Target firmware version : 1.0.56.61 or later]

Item	Spec.
Maximum number of connection per Border Router	100 nodes
Maximum number of connection per Router	64 nodes
Maximum number of hops	24 hops

In this section, we will introduce the network configuration pattern that verified the connection using one Border and 100 Routers/Leafs on the BP35C5 with the firmware version 1.0.56.61 or later.

14.1. Configuration of maximum number of connection per Border Router

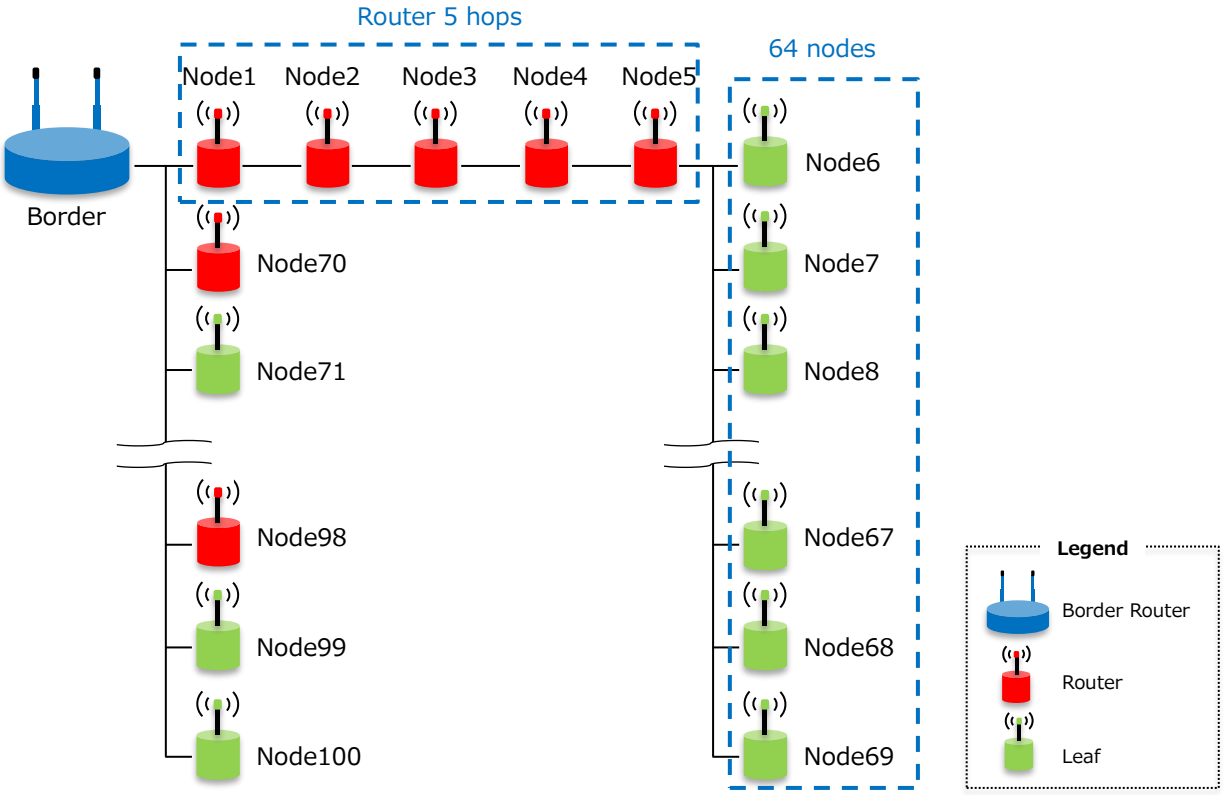
It is a star network configuratoin in which 100 nodes are connected directly under Border.



[1] BP35C5 can also provide a solution that can build a network with a maximum number of connection nodes of 1,000 by combining BP35C5 and a high-performance host MCU (Linux, etc.), but this document describes the specifications that BP35C5 itself can manage.

14.2. Configuration of maximum nunber of connection per Router

Of 100 nodes, connect 64 nodes ahead of 5 hops by Routers, and the remaining nodes are connected directly under Border.

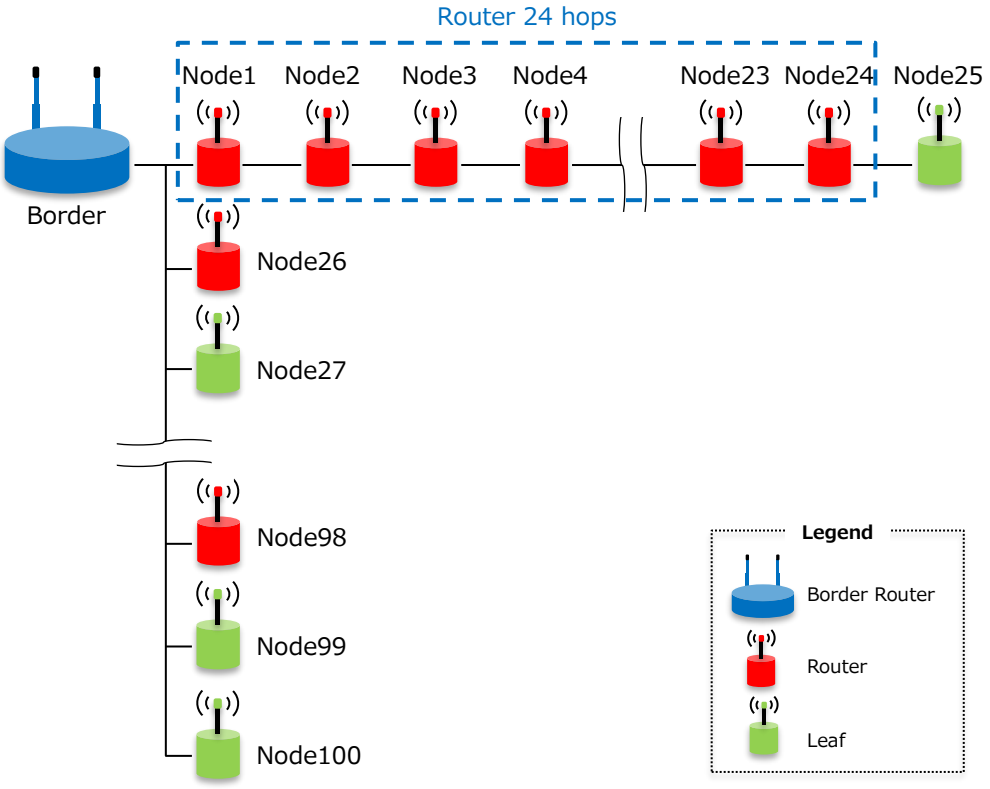


As shown in the figure above, it has been verified that 64 nodes can be connected to the Router 5 hops.

According to the specifications, 64 nodes can be connected to the Router 24 hops, but in multi-hop, data is passed by the bucket brigade method, so each node of the hopping route frequently sends data. And the radio waves are extremely congested. FAN exchanges management data to maintain the hopping route, but when communication data is concentrated due to the simultaneous connection of end nodes, it becomes impossible to exchange management data to maintain the route, and the hopping route is temporarily interrupted. The phenomenon becomes more pronounced as the number of hops increases. When it actually connected 64 nodes to 24 hops at once, the hopping route was interrupted, and it couldn't connect even after waiting for a long time. Therefore, it is necessary to control the hopping route so that the data is not excessively concentrated.

14.3. Configuration of maximum hops

Of 100 nodes, one node is connected to 24 hops, and the remaining nodes are connected directly under Border.



As mentioned in "14.2.Configuration of maximum nunber of connection per Router", it has been verified that 24 hops can be achieved as shown in the above figure unless a large number of nodes are connected at the end of the hopping route and the communication data is concentrated.

15. Communication distance

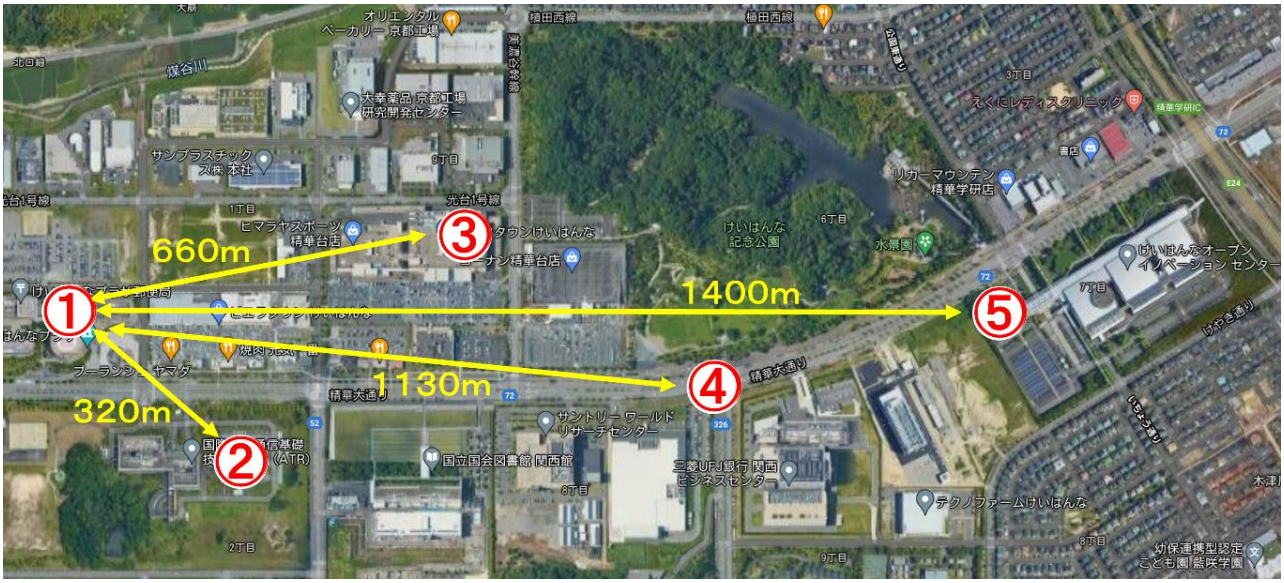
This chapter describes the measurement results of communication distance.

15.1. Communication distance between building roofs

The higher the antenna, the more obstacles such as buildings and the ground disappear, and the true communicaton distance can be measured. Therefore, we installed the antenna on the roof of the building and measured the communication distance.

The used antenna is 1019-008A (Max Gain 3dBi) manufactured by Staf corporation.

The points of the measurement field are as shown in the figure below:



Points ①, ②, ③ and ⑤ are on the roof of the building, and point ④ is on the ground.

Point ① was set as the Border, and pings (256 bytes, 100 times) were performed from the Border to the Routers of points ② to ⑤. As a result of measuring at 50kbps and 150kbps to verify the difference depending on the communication rate, the results are as shown in the table below:

Point	Distance	Antenna height of the Border	Antenna height of the Router	Packet Error Rate (PER)	
				on 50kbps	on 150kbps
①−②	320m	60m	15m	0%	0%
①−③	660m	60m	20m	0%	0%
①−④	1,130m	60m	2m	1%	22%
①−⑤	1,400m	60m	10m	0%	15%

The packet error rate is lower on 50kbps than on 150kbps. From this measurement result, it can be seen that if the communication rate is low, stable communication can be achieved even if the distance is long.

15.2. Communication distance on the ground

The antenna was installed at a position close to the actual height at which the wireless device will be installed, and the communication distance was measured.

The used antenna is 1019-008A (Max Gain 3dBi) manufactured by Staf corporation.

The measurement points are as shown in the figure below:

Map data ©2021 Google

The receiver side (Border Router) was fixed at the 0m point, the sender side (Router) was sequentially separated, and each point communicated 100 times by UDP communication (payload length 256 bytes).

The height of the antenna is 2m on the both sides. The communication results seen from the receiver side are as shown in the table below:

Distance (m)	50kbps		100kbps		150kbps		300kbps	
	RSSI(dBm)	PER(%)	RSSI(dBm)	PER(%)	RSSI(dBm)	PER(%)	RSSI(dBm)	PER(%)
1	-55.00	0.0	-41.00	0.0	-41.00	0.0	-41.10	0.0
50	-53.68	0.0	-52.50	0.0	-58.32	0.0	-64.19	0.0
100	-61.10	0.0	-63.20	0.0	-67.57	0.0	-60.64	0.0
150	-64.96	0.0	-65.10	0.0	-67.92	0.0	-69.53	0.0
200	-77.14	0.0	-73.12	0.0	-77.16	0.0	-77.90	0.0
250	-92.10	1.0	-91.86	8.0	-85.74	7.0	-86.70	0.0
300	-87.77	6.0	-83.85	0.0	-92.11	60.0	-91.74	14.0
350	-83.78	0.0	-89.33	0.0	Disconnected		-84.65	0.0
400	-88.32	0.0	-91.18	3.0			-90.78	20.0
450	-96.25	47.0	-91.49	1.0			Disconnected	
500	Disconnected		Disconnected					

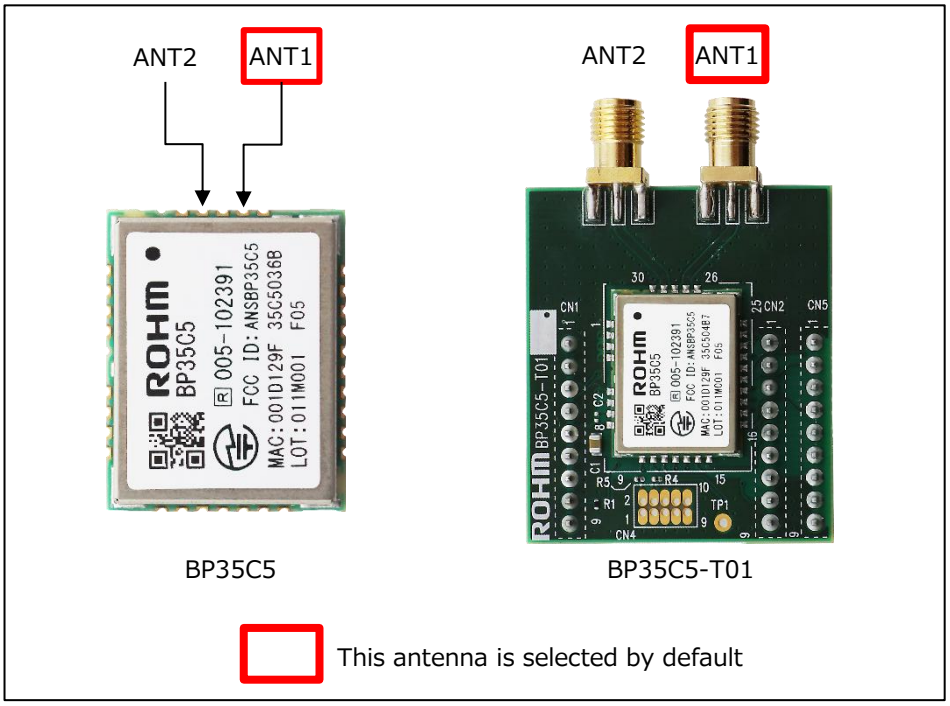
The communication distance is shortened on 150kbps, but it seems that it was affected by the surrounding conditions (the position of obstacles such as automobiles) at the measured time. If it was possible to measure under the same conditions as other rates, it is presumed that communication could have been possible up to around 400m.

In addition, the 50kbps PER (Packet Error Rate) shown in yellow shading is high, but this is because transmission was temporarily impossible due to the total transmission limit stipulated by the Japan Radio Law. Therefore, the communication performance is not bad.

16. Antenna

16.1. Antenna switching

The BP35C5 has two antennas, which are called antenna 1 (hereinafter, ANT1) and antenna 2 (hereinafter, ANT2), respectively.



The antenna to be used can be switched by using the rantsw command. This setting can be saved in the non-volatile area with the save command.

Mode	Command	Remarks
Use only ANT1	`rantsw 1`	Default
Use only ANT2	`rantsw 2`	
Diversity	`rantsw 0`	The receiving antenna is selected automatically.

16.2. Diversity

Diversity is a technology that improves communication quality by automatically selecting the antenna with the higher communication quality using multiple antennas.

When set to diversity, the BP35C5 receives radio waves from both ANT1 and ANT2 (Antenna Search) and receives packets from an antenna with strong radio wave strength.

The transmit antenna is selected as follows:

Up to 1.0.56.63:

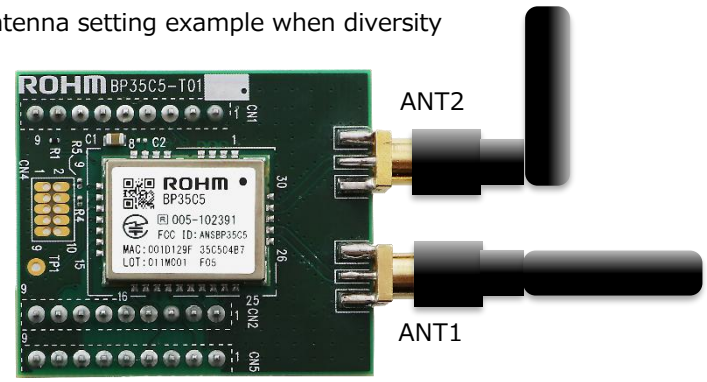
The radio waves are transmitted from either antenna selected during antenna search (50% chance of being transmitted from either antenna).

1.0.56.64 or later:

The radio waves are transmitted from the antenna that is determined to have strong radio wave strength upon reception.

One thing to note when using diversity is that antennas have directionality, so the ease of reception varies depending on the direction the radio waves are sent from. We recommend changing the angles of ANT1 and ANT2 to make it easier to receive radio waves sent from various angles.

Antenna setting example when diversity



17. Radio Law Certification

The information presented in this chapter is current as of May 12, 2022.

17.1. Japan

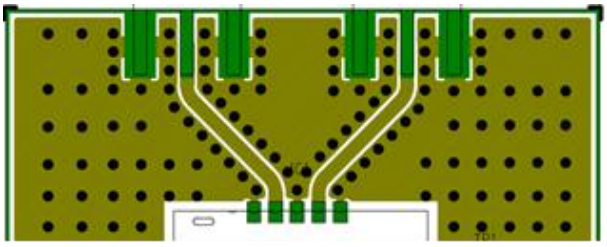
BP35C5 is certified by the Radio Law of Japan. Any antenna listed in the "BP35C5 Radio Law Certified External Antenna List" can be used without the need for additional certification. If you want to use an antenna other than those listed on the antenna list, please contact ROHM as additional certification is required.

17.2. North America (FCC)

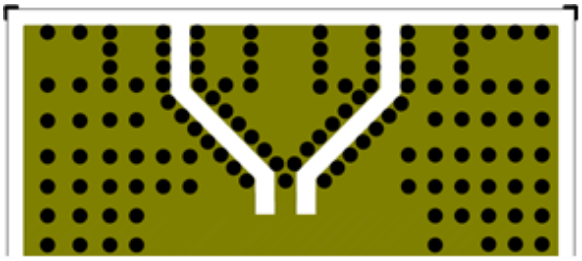
BP35C5 is FCC certified. To maintain FCC module certification, you must use a tested antenna type. If the antenna type is the same and the antenna gain is the same or less, it is possible to use an antenna other than those listed in the "BP35C5 Radio Law Certified External Antenna List".
The FCC also requires the use of antennas with a connector type of RP-SMA (reverse polarity SMA).
The FCC certification test for BP35C5 is conducted with the types of antennas shown in the table below.

Type	λ/2
Gain	3 dBi or less
Connector	RP-SMA

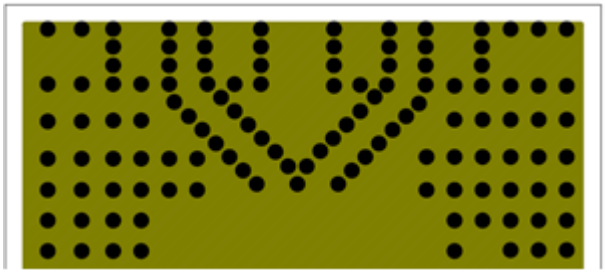
The RF part of the BP35C5 is certified using the SMA connector at the end of the PCB and the microstrip line layout as shown below. Host PCBs can maintain FCC module certification compliance by following these layout designs. Please contact us as we will provide PCB data.



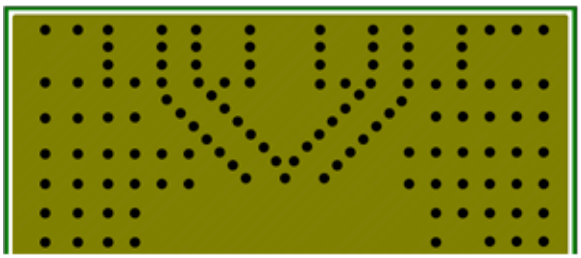
TOP LAYER



L2 LAYER



L3 LAYER



BOTTOM LAYER

PCB details.
4 layers through hole
FR-4
Thickness: 1.2mm

17.3. Others

The table below provides information on current national certifications. Please contact the certification body for the latest information and details.

Region No. <*domain*>	Region Name	Short Name	Rate (kbps) <*rate*>				Certification Status	Certification Outline
			50	100	150	300		
01	North America	NA	✓	-	✓	✓	Certified	Certification required, Test required
02	Japan	JP	✓	✓	✓	✓	Certified	Certification required, Test required
03	EU/UK	EU	-	-	-	-	Not Supported	Self-declaration, CE Report required
04	China	CN	-	-	-	-	Not Supported	Certification required, Test required
05	India	IN	-	-	-	-	Not Supported	Certification required, No test required, FCC/CE Report required
06	Mexico	MX	✓	✓	✓	✓	Uncertified	Certification required, Test required
07	Brazil	BZ	-	-	-	-	Uncertified	Certification required, Test required
08	Austraria/New Zealand	AZ/NZ	✓	✓	✓	✓	Uncertified	Self-declaration, FCC/CE Report required
09	Korea	KR	✓	✓	✓	✓	Uncertified	Certification required, Test required
0A	Philippines	PH	✓	✓	✓	✓	Uncertified	Certification required, No test required, FCC/CE Report required
0B	Malaysia	MY	✓	✓	✓	✓	Uncertified	Certification required, Test required, CE Report required
0C	Hong Kong	HK	✓	✓	✓	✓	Uncertified	Self-declaration, FCC/CE Report required
0D	Singapore	SG	✓	✓	✓	✓	Uncertified	Certification required, No test required, FCC/CE Report required
0E	Thailand	TH	✓	✓	✓	✓	Uncertified	Certification required, No test required, FCC/CE Report required
0F	Vietnam	VN	✓	✓	✓	✓	Uncertified	Certification required, Test required、 FCC/CE Report required

*1: FCC Report = Test report for North America.

*2: CE Report = Test report for Europe.

*3: Test required = FCC/CE reports cannot be diverted and must be tested.

*4: Self-declaration = Declare vendors to comply with regulations, not state certification.

18. Radio OFF Mode

The BP35C5 also has what is called "Radio OFF Mode" or "Standby Mode". This is a non-communication mode in which the radio is disabled.
In BP35C5, the radio can be turned off by setting the terminal operation mode to "non-operation mode".
By setting it to non-operation mode, current consumption is reduced compared to the receive standby state (ready to receive at any time).
The current consumption is always 20 mA (TYP) in receive standby state, but 5.5 mA (TYP) in Radio OFF Mode.
However, since the radio is turned off, communication is not possible during this time.

* The current values described in this chapter are actual measurement values (TYP) measured at room temperature of 25 degrees Celsius and are for reference only.

18.1. How to switch

As a preliminary preparation, the following commands must be executed to set and save the non-operating mode.

```
> atstart 0        ← Set the terminal operation mode at startup to "non-operation mode"
> save             ← Save settings (or svrst)
```

With this advance preparation, the system will start in non-operating mode from the next startup.

To switch from non-operating mode to operating mode, use the "init" command. Do one of the following

```
> init 1           ← Switch to Border Router
> init 2           ← Switch to Router
> init 3           ← Switch to Leaf
```

To switch from opeating mode to non-operating mode, use the reset command.

```
> reset            ← Switch to "non-operating mode" by rebooting
```

18.2. Notes on the init command

The change of terminal operation mode by the "init" command is valid only for the change from non-operatiing mode (0) to operating mode (1 to 3).
Changes from operating mode (1 to 3) to non-operating mode (0) and from operating mode (1 to 3) to other operating modes are invalid.

19. Transmission Power Setting

The BP35C5 has three levels of transmit power (20 mW, 10 mW, and 1 mW), which can be referenced, set, and saved with commands.
For details on how to check or change the settings, please contact ROHM.

20. Parameters to be saved in non-volatile memory

Some configuration parameters can and cannot be saved in non-volatile memory with the save command. The table below summarizes them for clarity.

Category	Command	Explanation	Save(*)	Remarks
General	help	Display help messages	-	
	vers	Display full firmware version	-	
	vernum	Display simple firmware version	-	
	reset	Restart the Wi-SUN module	-	
	echo	Echo-back settings	Yes	
	json	Set JSON string input/output	Yes	
	baud	Set serial communication speed	Yes	Save immediately
Display connection setting	mode	Set operational mode	Yes	
	auth	Set authentication security behavior	Yes	
	chrate	Set transmission rate	Yes	
	chan	Set start/end channel	Yes	
	rccal	Set RSSI threshold for CCA operation of PHY	Yes	
	mac	Display of MAC address	-	
	macf	Set incoming MAC address filtering	Yes	
	mtxctl	Set duty cycle of MAC packet	-	
	pan	Set PAN ID	Yes	
	netname	Set Network ID	Yes	
	ip	Set IPv6 address	Yes	
	init	Set role	No	
	atstart	Role at startup	Yes	
	tcpcon	Manual TCP Connection	-	
	tcpdis	Manual TCP Disconnection	-	
	rantsw	Antenna to be used	Yes	
	rfec	FEC function enable	Yes	
	sleep	Sleep and awake	-	
Border Router Management	leaseip	DHCPv6 server lease IP address	Yes	
	leaserng	DHCPv6 server lease IP address range	Yes	
	nodef	MAC address filtering of allowed connection nodes	Yes	
	fnode	Display connected nodes	-	
Connection status	stat	Display terminal status	-	
	rstat	Display of physical layer (PHY-RADIO) statistics	-	
	mstat	Display of MAC statistics	-	
	fstat	Display of FAN (MAC-FAN) information	-	
	chconfig	Display of frequency aread in use and TX rate	-	
	chcur	Display of currently used channel number	-	
	fmseckey	Display of FAN MAC security keys	-	
	nebr	Display of neigbor node information	-	
	parent	Display of parent node information	-	
	rplinf	Display information about RPL	-	
	tcpstat	Display of TCP status	-	
	rplsr	Display of RPL source routing table	-	
	leased	Display of IPv6 addresses leased by DHCPv6 server	-	
Data transmission	udps	UDP data transmission (binary)	-	
	udpst	UDP data transmission (text)	-	

Category	Command	Explanation	Save(*)	Remarks
	tcps	TCP data transmission	-	
	ping	ping execution	-	
Data transmission and reception settings	udpopts	UDP data TX/RX settings		
	comp_hdr	UDP Header Compression setting	No	
	comp_csum	UDP Checksum suppression setting	No	
	disp_len	Data length display setting when TX/RX completion	Yes	
	disp_port	Port display setting when TX/RX completion	Yes	
	disp_rssi	RSSI display setting when RX completion	Yes	
	send_done	TX completion display setting	Yes	
	send_port	Default send port setting for udps	Yes	
	send_port_text	Default send port setting for udpst	Yes	
	listen_port	RX port setting for udpr	Yes	
	listen_port_text	RX port setting for udprt	Yes	
	tcpopts	TCP data TX/RX settings		
	auto_connect	Automatic TCP connection behavior setting	Yes	
	log	Display setting for operation log	Yes	
	disp_len	Data length display setting when TX/RX completion	Yes	
	disp_port	Port display setting when TX/RX completion	Yes	
	send_done	TX completion display setting	Yes	
	send_port	Default send port setting for tcpcon, tcpdis and tcps	Yes	
	listen_port	TCP server port setting	Yes	
	idle_minites	No communication monitoring time setting	Yes	
	rto_sec	Retransmission timer setting	Yes	
	maxrtx	Retransmission count setting	Yes	
	syn_maxrtx	SYN retransmission count setting	Yes	
	mss	MMS(Maximum Segment Size) setting	Yes	
Parameter control	param	Display parameter	-	
	save	Save parameter	-	
	clear	Clear parameter	-	
	svrst	Save parameter and reset	-	
	clrst	Clear parameter and reset	-	
Remote command	rmtcmd	Remote command (Command execution on remote)	-	
	rmtopts	Display of settings about remote command		
	send_done	TX completion display setting	Yes	

*Meaning of the "Save" column:

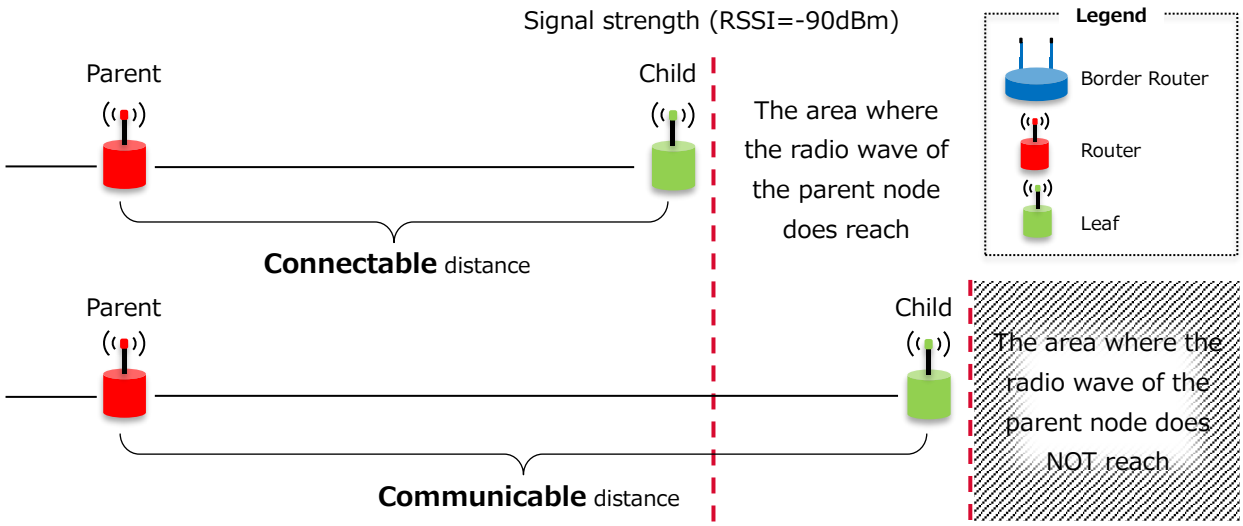
"-" is a command that cannot be set.

"Yes" is a command that can be set and saved.

"No" is a command that can be set but cannot be saved.

21. Distance of connectable and communicable

This chapter explains the difference between connectable and communicable distance.
The connectable distance is the maximum distance that can be connected to the parent node.
The communicable distance is the maximum distance that can be communicated between nodes.
As shown in the figure below, the connectable distance is shorter than the communicable distance.



When a child node connects to a parent node, the FAN standard requires that at Join State 4 (RPL routing state), the parent node to be connected is selected from among the neighbor nodes, and the radio signal strength of the candidate parent node must be above a threshold value. The threshold is vendor-specified, For BP35C5, the threshold value is radio signal strength RSSI=-90dBm.
Therefore, even if the threshold is exceeded, communication is still possible, but reconnection is not possible. So, it is necessary to confirm that it is in a connectable location when installing the node.

21.1. Installation procedure at connectable distance

This section describes the procedure for installing the child node within a connectable location.

(1) Parent and child nodes are connected in close proximity.
(2) With the connection established, move the child node to the desired location and temporarily install it. Then, confirm several times that communication is possible using the ping command.
(3) Check the radio radio strength RSSI with the nebr command, and check several times whether it is within the threshold range.
(4) If it is within the connectable range, reset the child node once and check that it is reconnected.

21.2. Confirmation of radio signal strength

To check the radio signal strength of the parent node, use the nebr command. An example of the nebr execution is shown below.

```
>nebr
nebr num:3, max:128, rank:312(2)
nebr <001d129f35c500be>: 226(-41)   <2001:db8::4>
nebr <001d129f35c501d9>: 240(-41)   <2001:db8::3>
nebr <001d129f35c5025b>: 184(-47)   <2001:db8::1>   ← Parent node information
```

In this example, the last line corresponds to the parent node (the line that matches the MAC address of the parent node).

The yellow marker part of the line is the value to be compared with the threshold value. If this value is -90 or more, it means that it is within the threshold range.

A description of the values displayed by nebr will be given later.

21.3. Display contents of nebr command

To explain the display of the nebr command, the execution example is shown.

The example below is formatted up to firmware 1.0.56.63.

```
>nebr
nebr num:3, max:128, rank:312(2)
nebr <001d129f35c500be>: 226/133(-41)   <2001:db8::4>
nebr <001d129f35c501d9>: 240/132(-41)   <2001:db8::3>
nebr <001d129f35c5025b>: 184/123(-47)   <2001:db8::1>
```

The display format of nebr is as follows.

```
nebr num:NUM_OF_NBR, max:NBR_MAX, rank:RANK(DAGRank)
nebr <MAC_ADDR1>: ETX1/RSL_EWMA1(RSSI1)   <IP_ADDR1>
        ...
nebr <MAC_ADDRn>: ETXn/RSL_EWMAn(RSSIn)   <IP_ADDRn>
```

The example below is formatted for firmware 1.0.56.64 or later.

```
>nebr
nebr num:3, max:128, rank:312(2)
nebr <001d129f35c500be>: 226(-41)   <2001:db8::4>
nebr <001d129f35c501d9>: 240(-41)   <2001:db8::3>
nebr <001d129f35c5025b>: 184(-47)   <2001:db8::1>
```

The display format of nebr is as follows. EWMA has been removed.

```
nebr num:NUM_OF_NBR, max:NBR_MAX, rank:RANK(DAGRank)
nebr <MAC_ADDR1>: ETX1(RSSI1)   <IP_ADDR1>
        ...
nebr <MAC_ADDRn>: ETXn(RSSIn)   <IP_ADDRn>
```

NUM_OF_NBR(num) indicates the number of neighbor nodes currently known by the own node. In the example shown, there are 3 nodes.

NBR_MAX(max) indicates the maximum number of neighbor nodes. In the example shown, the maximum is 128 nodes.
RANK and DAGRank are values that indicate the network position of the own node.
RANK is derived from parent RANK + parent ETX.
DAGRank is the value of the integer part of RANK divided by 128. The smaller the DAGRank, the closer it is to the border router.

The second and subsequent lines of nebr are information about neighboring nodes (a neighboring node is a node that exists around its own node).
MAC and IP addresses are omitted.
ETX (Expected Transmission count) indicates the communication success rate; a smaller value indicates a higher success rate.
RSL_EWMA (Received Signal Level_Exponentially Weighted Moving Average) is the moving average value of the radio signal strength. -174 to +80 dBm is expressed by 0 to 254. 255 means missing data. This value used to determine which parent node can be connected.
RSSI is a value that expresses the radio signal strength in dBm. This is not the moving average, but the signal strength of the most recently received frame is displayed.

22. Firmware update protocol

The BP35C5 can be updated with firmware from the host via UART.
Therefore, FOTA (Firmware Over The Air) can be realized by downloading firmware from the Border Router to the Router and Leaf via the network and retaining it on the host side.
For details on the firmware update procedure, please contact ROHM.

23. LED control

The BP35C5 pin GPIOA0/SDA (18) is assigned the function of status indication using an LED, and its output switches according to the status. In the default operation mode, it is configured to blink in the broadcast slot. For details on how to change the operation mode, please contact ROHM.

24. Notes

24.1. Wireless communication

1. Wireless communication may cause unstable communication due to radio environment or communication environment, and therefore, data transfer is not 100% guaranteed. ROHM Co., Ltd (herein after referred to as **the Company**) shall not be responsible for any data loss.
2. UDP does not provide the arrival of successive packets and does not guarantee the arrival of data.
3. Perform a thorough validation of this product by the customer before incorporating it for full-scale operation.
4. The Company shall not be liable for any damage or malfunction caused by data interception, loss, theft, plagiarism or leakage to a third party.

24.2. Changes

This instruction manual and the sample scripts used are subject to change without prior notice.

24.3. Firmware

24.3.1. Firmware licensing

With respect to the built-in firmware of this Product, agree to the following licensing prior to use.

1. This software is firmware dedicated to BP35C5. Do not use the firmware for any product other than BP35C5.
2. Do not assign, transfer, sub-license, or lend this Software to any third parties.
3. Reverse engineering, decompilation, disassembly, reproduction, and change of this Software are prohibited.
4. ROHM shall not guarantee any and all operations performed by using this Software.
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6. In the event of a defect or the like to be attributed to ROHM under normal use for the Software during the first six (6) months from (1) Initial delivery date of BP35C5 or (2) Date of this specification change, customer must notify ROHM immediately.
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8. In any case, the amount borne by ROHM due to defects etc. of the software shall be no more than the last six (6) months of the total sales value of BP35C5 from ROHM to the customer.
9. If the provisions of Article 19.1 of this specification, the provisions of the basic contract to be concluded, any contracts and memoranda, incidental thereto, and other specifications of this specification between customer and ROHM contradict or conflict, the provisions of this section shall prevail.

24.3.2. Firmware version

1. The version of firmware written to this Product is the latest version at the time when it is manufactured.
2. Firmware may not be the latest version depending on the shipment timing.
3. The version of firmware is subject to change without prior notice. ROHM shall not be in any way responsible or liable for damages of customers caused by such changes.
4. The version of firmware written to this Product cannot be distinguished by the appearance of the Product.
5. The same firmware is written to products contained in the same package.

24.3.3. Method for checking firmware version

Firmware version can be checked by using "vers" command.

For details, refer to information in command manual.

24.3.4. Current value and time

1. Expect as otherwise noted, the current value and time described in this manual is actual measurement values (TYP) at room temperature of 25 degrees Celsius and is just a reference value.

25. Revision History

Ver.	Date	Details	Target firmware version
1.0.0	2020/06/08	Initial version	1.0.56.60 or later
1.0.1	2020/08/03	Added “0. Connection Time”	1.0.56.60 or later
		Added “1. Power Consumption”	1.0.56.60 or later
1.0.2	2021/07/29	Added “2. Throughput and latency (for reference)”	1.0.56.60 or later
		Added “3. Turnaround time (for reference)”	1.0.56.60 or later
		Added “14. Maximum number of connections”	1.0.56.61 or later
		Added “15. Communication distance”	1.0.56.60 or later
		Updated “16.3. Firmware”	1.0.56.60 or later
1.0.3	2021/10/28	Added “Antenna”	1.0.56.60 or later
1.0.4	2022/05/10	Added “Radio Law Certification”	1.0.56.60 or later
1.0.5	2022/06/28	Added “Radio OFF Mode”	1.0.56.60 or later
		Added “Transmission Power Setting”	1.0.56.60 or later
		Added “Parameters to be saved in non-volatile memory”	1.0.56.60 or later
		Added “Distance of connectable and communicable”	1.0.56.60 or later
1.0.6	2022/07/26	Corrected how to reset listen_port and listen_port_text to default in “How to Use a Non-default Port for UDP/TCP”	1.0.56.60 or later
1.0.7	2024/05/31	Added “22.Firmware update protocol”	1.0.56.60 or later
		Added “23.LED control”	1.0.56.60 or later
		Improved accuracy of values in “Throughput and latency (for reference)”	1.0.56.60 or later
		Changed the description of “16.2. Diversity” due to changes in the diversity algorithm in firmware version 1.0.56.64	1.0.56.64 or later
		Changed “21.3. Displayed contents of the nebr command” due to changes in the display format of the nebr command in firmware version 1.0.56.64	1.0.56.64 or later
1.0.8	2026/1/26	Corrected the description of the transmit current consumption in “11. Power Consumption (for reference)” and added supplementary information	1.0.56.60 or later
		Changed the description of “19. Transmission Power Setting”	1.0.56.60 or later
		Changed the description of “22. Firmware update protocol”	1.0.56.60 or later
		Changed the description of “23. LED control”	1.0.56.60 or later

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