Network Latency Measurements in the DXCluster Node Network

This document outlines an analysis of latency times between nodes in the DXCluster network, accounting for factors such as network topology, routing protocols, and diversity in node software implementations.

It does not claim to be in any way an extensive study, due to the difficulties involved. It is limited to a sample of 14 nodes, which, although representing 4% of the network, can be a realistic approximation.

Hardware Setup

The tests were conducted using a VPS with the following specifications:

- CPU: 1

- RAM: 16 GB

- Storage: 50 GB HDD

- Bandwidth: > 1 Gbps

The VPS has a static IP address and is located in Europe.

Software Setup

Two identical DXSpider nodes were deployed using Docker containers on the same VPS. The nodes were named EA3CV-8 and EA3CV-9.

Node software:

- DXSpider version: v1.57 (build 547 git: mojo/343854b3[r])

- Runtime environment: Perl v5.30.3 on Linux Alpine 3.16

Network Interconnections

For this test, partners in EU, NA, SA, AF and OC were requested. Requests were sent both to nodes with more users and links, as well as to more modest ones, both DXSpider and CCCluster. The test nodes were isolated from any users.

Each test node was isolated from user traffic and maintained a single connection to a neighboring node at any given time.

Testing Approach

Test Design

1. The two test nodes were synchronized for accurate timestamp comparisons.

2. Latency measurements were collected using:

   - PC92K sentences (broadcast sentences across nodes).

   - PC11/PC61 sentences (spots).

Partner Nodes

The nodes that agreed to participate in the test were:

EA3CV-8 Connections	EA3CV-9 Connections
CX2SA-8	CX2SA-8
EA4RCH-5	EA3CV-2
EA4URE-3	EA8URL-2
N4VFF-2	HG8PRC
PY1NB-4	K4JW
VE7CC-1	PA4JJ-3
	SM4UZM-1
	VE9SC
	VK5GR-2

Testing period: December 5 to December 9, 2024

Software modifications

Modifications applied to the code of the test nodes in the DXDebug.pm module

Before:

```
my $t = time;

...

my $str = "$t^$tag$l";
```

After:

```
my $t = time;

my ($sec, $usec) = gettimeofday();

my $tm = $sec * 1000 + int($usec / 1000);

...

my $str = "$tm^$tag$l";
```

Before:

1733988348^(chan) <- I EA4URE-5 PC92^EA3CV-2^26748^A^^1HP1XV:190.141.201.76^H97^

After:

1733988348278^(chan) <- I EA4URE-5 PC92^EA3CV-2^26748^A^^1HP1XV:190.141.201.76^H97^

Measurement Methodology

PC92K Command Latency

The PC92K sentences is only generated and progressed by the network nodes that have it deployed and enabled. This traffic time has the same behavior as any other traffic on the network, it is spread by flood without any modification. Its limitation is in the types of nodes that do not have this type of statements implemented in their code, or not to their full extent. For this reason, this test leaves out nodes of the type: CCCluster, ARCCluster, CLX, DXNet, ..., but since the largest percentage are nodes of the DXSpider type (approx. 74%), with a high degree of updating, the test can be considered valid. It was measured end-to-end, that is, it was generated in EA3CV-8 and received in EA3CV-9 for all the cases studied.

$$Time/Hop = \frac{\sum|t_1 - t_2|}{nh}$$

- t_1: Timestamp at EA3CV-8
- t_2: Timestamp at EA3CV-9
- n: Number of measurements (500 per node pair)
- h: Number of hops

Overall Average Latency:

$$Overall\ Latency\ = \frac{\sum|t_1 - t_2|}{nhm}$$

- m: Total number of hop paths

PC11/PC61 Spot Delivery Latency

It is used to calculate the difference in the delivery of spots, from the source node to the test nodes that act as clients. It is measured as the difference in absolute value between the two test node with the same origin node. As the same node can have more than one connection link with other nodes, it must be taken into account that the same spot will arrive through more than one link, and that only one of these will be broadcast to the following neighboring nodes. This means that the one that arrives with the fewest hops does not always propagate, because the propagation times depend not only on the node through which it transits, but is a function of the physical medium, bandwidth, flow, etc. The values obtained for the end-to-end mean were calculated with:

$$Latency\ per\ Hop = \frac{\sum|t_1 - t_2|}{n}$$

- t_1: Timestamp at EA3CV-8
- t_2: Timestamp at EA3CV-9
- n: Number of measurements

Conclusions Report

Data Analyzed

Average Propagation Times (ms):

High Load Nodes (1000-1500 users):

- Examples: WA9PIE-2, VE7CC-1, DH1TW-2, EA4RCH-5
- Average: 111.57 ms
- Standard Deviation: 43.06 ms

Low Load Nodes (0-300 users):

- Examples: GB7DJK, EA3CV-2, EA4URE-2
- Average: 69.17 ms
- Standard Deviation: 42.06 ms

Average Difference: *42.4 ms (less than 0.05 seconds), within the imperceptible range* for end users.

Hop Distribution: The number of hops needed to complete communication is consistent across the network, with most routes in the range of 2 to 5 hops:

Most Common Hops:

- 2 hops: 20,003 routes.
- 3 hops: 57,289 routes.
- Extreme Hops (6-9): Represent less than 1% of the total and do not show substantial increases in average times.

Specific Node Comparison by Load:

High Load Nodes:

- WA9PIE-2: Average Time: 96.51 ms
- VE7CC-1: Average Time: 189.13 ms
- DH1TW-2: Average Time: 86.81 ms
- EA4RCH-5: Average Time: 77.60 ms

Low Load Nodes:

- GB7DJK: Average Time: 28.57 ms
- EA4URE-2: Average Time: 56.17 ms
- EA3CV-2: Average Time: 15.67 ms

Analysis Results

Time Difference Test

A Student's t-test for independent samples was used, with the following calculated values:

- Mean of Group 1 (High Load): 111.57 ms
- Mean of Group 2 (Low Load): 69.17 ms
- Standard Deviation of Group 1: 43.06 ms
- Standard Deviation of Group 2: 42.06 ms
- Sample Size (n1 = n2): 4 nodes

The formula to calculate the t-value is:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where:

- $\bar{x}_1 \, and \, \bar{x}_2$ are the sample means,
- $s_1^2 \, and \, s_2^2$ are the sample variances,
- $n_1 \, and \, n_2$ are the sample sizes.

After calculating the t-value, a p-value is associated with this distribution. In this analysis:

- p-value: 0.066

Definition of p-value

It is a statistical measure that indicates the probability of obtaining the observed results if there were no real differences between the compared groups.

In this case, a p-value greater than 0.05 indicates that the observed differences in times are not statistically significant.

Consistency in Times by Hops

Even for routes with 6 to 9 hops, average times remain within a range of less than 0.5 seconds. This behavior demonstrates efficient traffic management, with the topological complexity not significantly affecting performance.

Practical Relevance for Users

The maximum observed propagation time is approximately 0.28 seconds, even in the most extreme cases. Differences of less than 0.5 seconds are not perceptible in practical terms for end users, who do not experience significant delays in information transmission.

General Conclusion

Based on the analysis of propagation times, hops, and node load:

- It doesn't matter whether you connect to a node with many users or links.
- The differences in propagation times are minimal and not statistically significant or perceptible to users.
- The average times for high-load nodes (111.57 ms) and low-load nodes (69.17 ms) do not represent a practical difference.
- The network is robust and efficient.

Regardless of load or number of hops, propagation times are consistent and remain within acceptable limits.
Even in scenarios with long routes (up to 9 hops), the times stay within acceptable ranges.
For the end user, the experience is uniform.

The variations in average times, which are less than 0.5 seconds, are below the perceptible threshold in information transmission.
This confirms that the network architecture ensures consistent performance for all users, regardless of the connection node.

Recommendation

The data presented supports the idea that the choice of connecting to a node with a high or low load does not significantly impact the propagation time of information. Therefore, users can connect to any node without worrying about its load or position in the network.

However, what really defines which node is more suitable for a user is not just the number of connected users, but the quality of service that the node can offer. This is largely dependent on factors such as:

1. **Guaranteed Availability (SLA)**

   Nodes with a high SLA (*Service Level Agreement*) tend to offer higher reliability due to robust infrastructure. This includes electrical redundancy (UPS), stable links, and regular maintenance.

2. **Active Management by Sysops:**

   It is essential for node administrators to carry out continuous management, including:
   - Proactive monitoring of the node's performance to identify potential failures or degradation.
   - Regular software updates to ensure compatibility and security.
   - Prompt resolution of technical incidents to minimize impact on users.

   Therefore, while technical differences between nodes in terms of propagation times are minimal and not perceptible to end users, the stability and quality of service directly depend on the sysops' commitment and dedication to maintaining their nodes in optimal condition.

Annexes

PC92K Overall Average Time/Hop

Examples of the calculation for a sample

Average processing time

Test-1 PC92K

Test-2 PC92K

Test-3 PC92K

Test-4 PC92K

Test-1 PC11/PC61

Test-2 PC11/PC61

Test-3 PC11/PC61

PC92K Overall Average Time/Hop

	ORIGIN				
DESTINATION	**PY1NB-4**	**EA4URE-5**	**EA4RCH-5**	**CX2SA-8**	**N4VFF-2**
K4JW	127.61 ms	121.88 ms	102.75 ms		
VE9SC	149.63 ms	38.19 ms	93.10 ms	108.79 ms	158.86 ms
PA4JJ-3	145.86 ms	45.67 ms	88.61 ms	69.33 ms	152.86 ms
VK5GR-2	157.06 ms	101.70 ms	103.18 ms	276.60 ms	173.44 ms
CX2SA-8	117.70 ms	89.53 ms	144.91 ms	165.83 ms	
SM4UZM-1	157.07 ms	42.10 ms	79.86 ms	81.96 ms	67.43 ms

Example of the calculation for a sample of PC11/PC61

```
EA3CV-8 <- N4VFF-2  ...  <- EA3CV-2 -> VE9SC -> EA3CV-9

        <- H27      ...  <- H30 H30 ->   H29 ->
```

EA3CV-8

```
1733768228210^(chan) <- I N4VFF-2 PC61^14202.0^CU4AN^ 9-Dec-
      2024^1817Z^IOTA EU-   175^CT7BOD^EA3CV-2^169.155.237.88^H27^~
```

EA3CV-9

```
1733768228168^(chan) <- I VE9SC PC61^14202.0^CU4AN^ 9-Dec-
      2024^1817Z^IOTA EU-175^CT7BOD^EA3CV-2^169.155.237.88^H29^~
```

t1 = 1733768228210

t2 = 1733768228168

|t1-t2| = **42 ms**

Hops(t1) = (H30-H27) + 1 = **4 hops**

Hops(t2) = (H30-H29) + 1 = **2 hops**

Intermediate nodes = (H30-H27) + (H30-H29) + 1 = **5 nodes**

Example of the calculation for a sample of PC92K

```
EA3CV-8 -> N4VFF-2 ->  ...     -> SM4UZM-1 -> EA3CV-9

    H99 ->     H98 ->  ... H95 ->      H94 ->
```

EA3CV-8

```
1733772637005^(chan) -> D N4VFF-2 PC92^EA3CV-8^70237^K^5EA3CV-
      8:5457:547^1^1^H99^
```

EA3CV-9

```
1733772637237^(chan) <- I SM4UZM-1 PC92^EA3CV-8^70237^K^5EA3CV-
      8:5457:547^1^1^H94^
```

t1 = 1733772637005

t2 = 1733772637237

t2-t1 = **232 ms**

Hops = (H99-H94) + 1 = **6 hops**

Intermediate nodes = (H99-H94) + 1 = **6 nodes**

Average processing time per node = (t2-t1)/(Intermediate nodes) = **46.40 ms**

Average processing time

PC61 -> **EA3CV-8** -> PC61

PC61 approx. **9 ms**

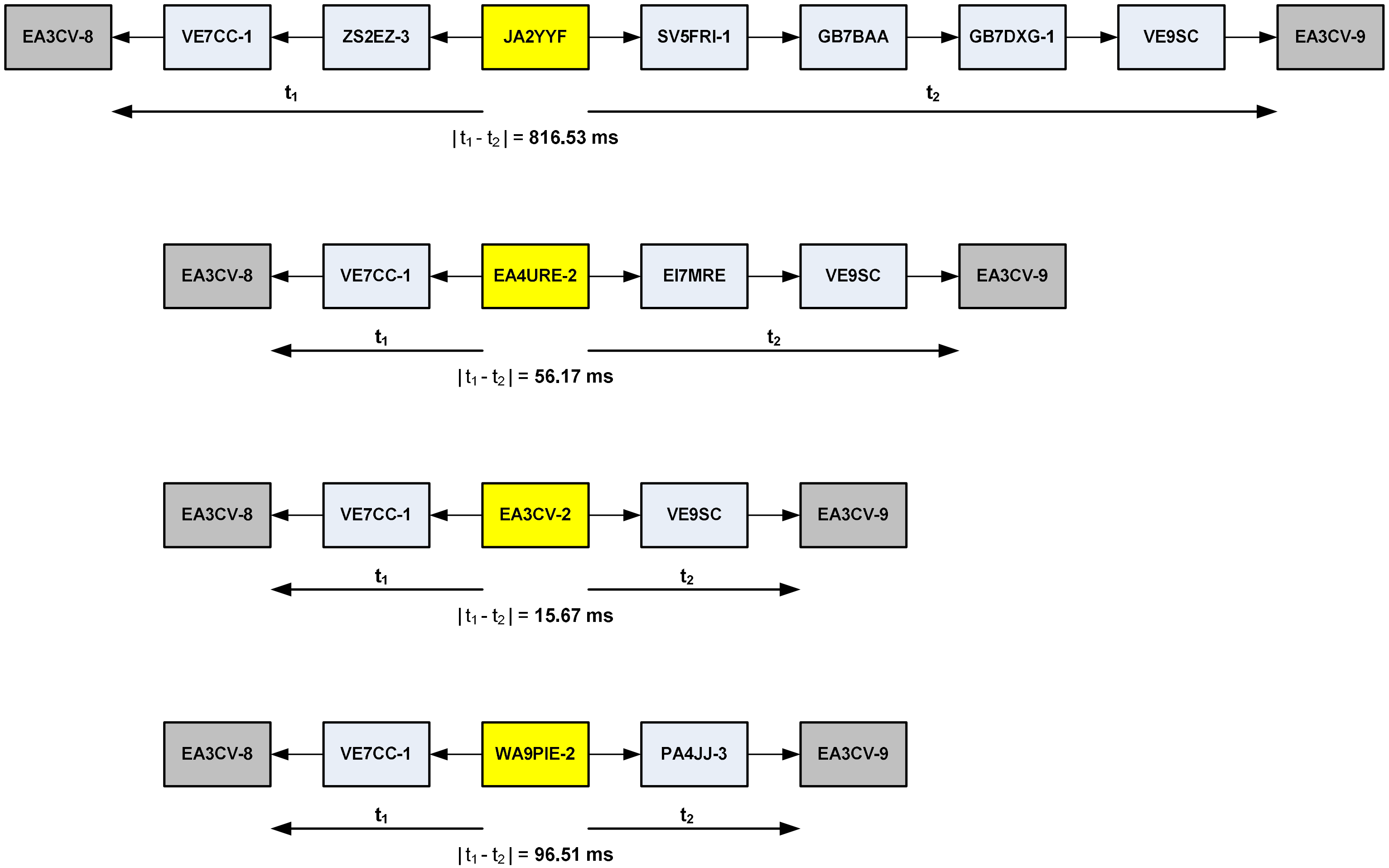
PC92K -> **EA3CV-8** -> PC92K

PC92K approx. **2 ms**

PC92C -> **EA3CV-8** -> PC92C

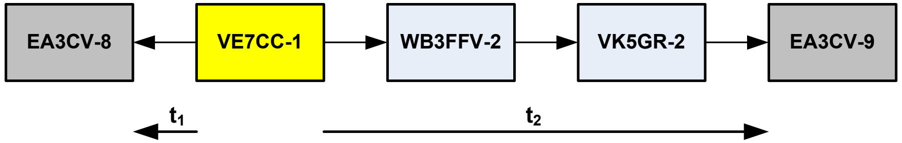
PC92C approx. **2/14 ms**

TEST-1 PC11/PC61

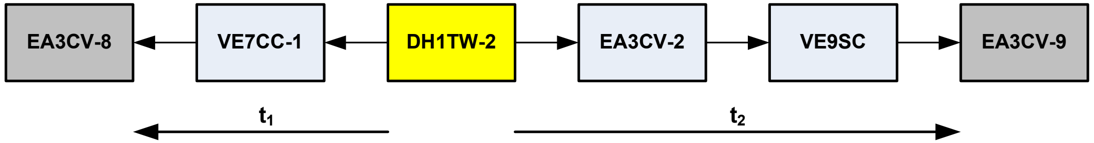


EA3CV 20241209

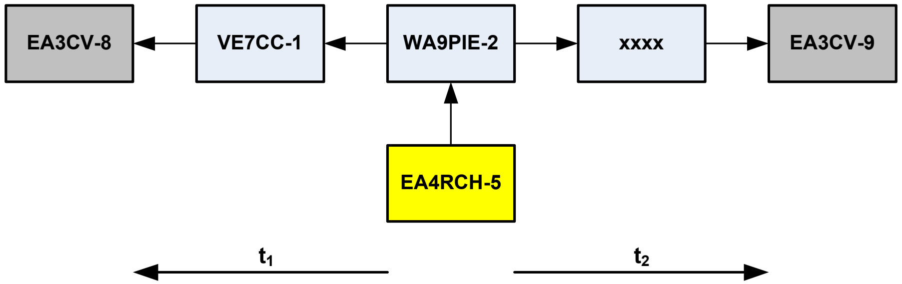
TEST-2 PC11/PC61



$|t_1 - t_2|$ = **189.13 ms**

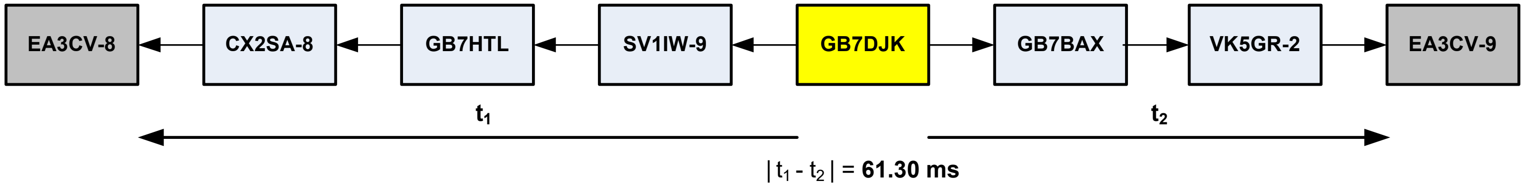


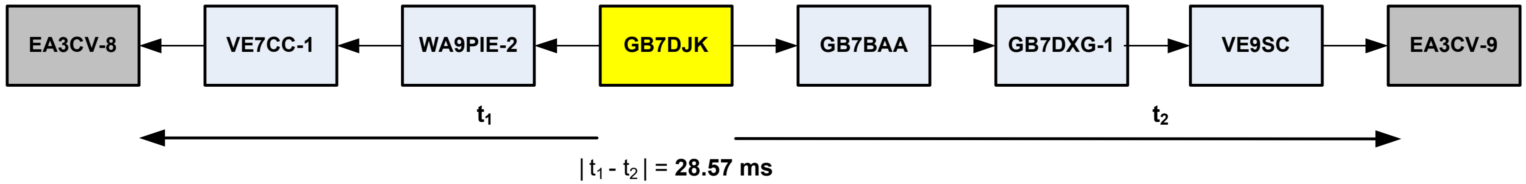
$|t_1 - t_2|$ = **86.81 ms**

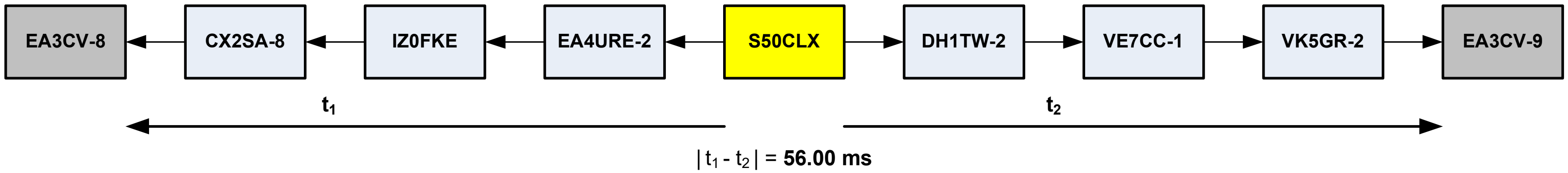


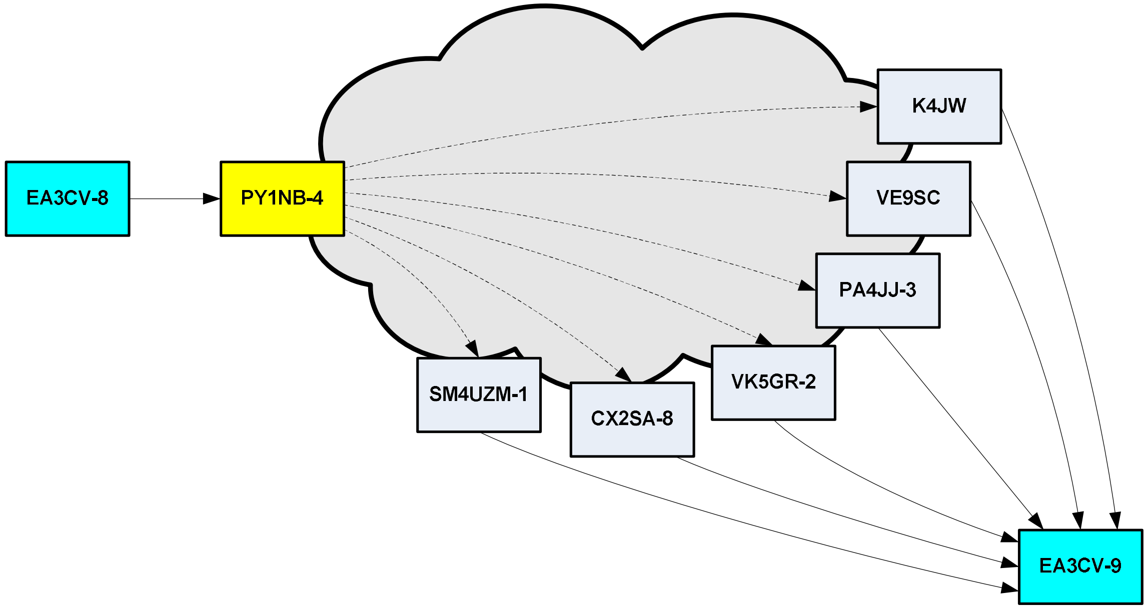
$|t_1 - t_2|$ = **77.60 ms**

TEST-3 PC11/PC61









K4JW

Hops	Average Time	Time/Hop
7	939.53 ms	134.22 ms
8	940.49 ms	117.56 ms
9	974.25 ms	108.25 ms

Overall Average Time/Hop: 127.61 ms

VE9SC

Hops	Average Time	Time/Hop
5	948.00 ms	188.72 ms
6	960.00 ms	158.17 ms
7	936.00 ms	134.11 ms
8	940.67 ms	117.50 ms

Overall Average Time/Hop: 149.63 ms

PA4JJ-3

Hops	Average Time	Time/Hop
6	942.44 ms	157.07 ms
7	938.39 ms	134.06 ms
8	950.75 ms	118.84 ms

Overall Average Time/Hop: 145.86 ms

VK5GR-2

Hops	Average Time	Time/Hop
6	944.14 ms	157.36 ms
7	929.50 ms	132.79 ms

Overall Average Time/Hop: 157.06 ms

CX2SA-8

Hops	Average Time	Time/Hop
7	947.50 ms	135.36 ms
8	941.00 ms	117.62 ms

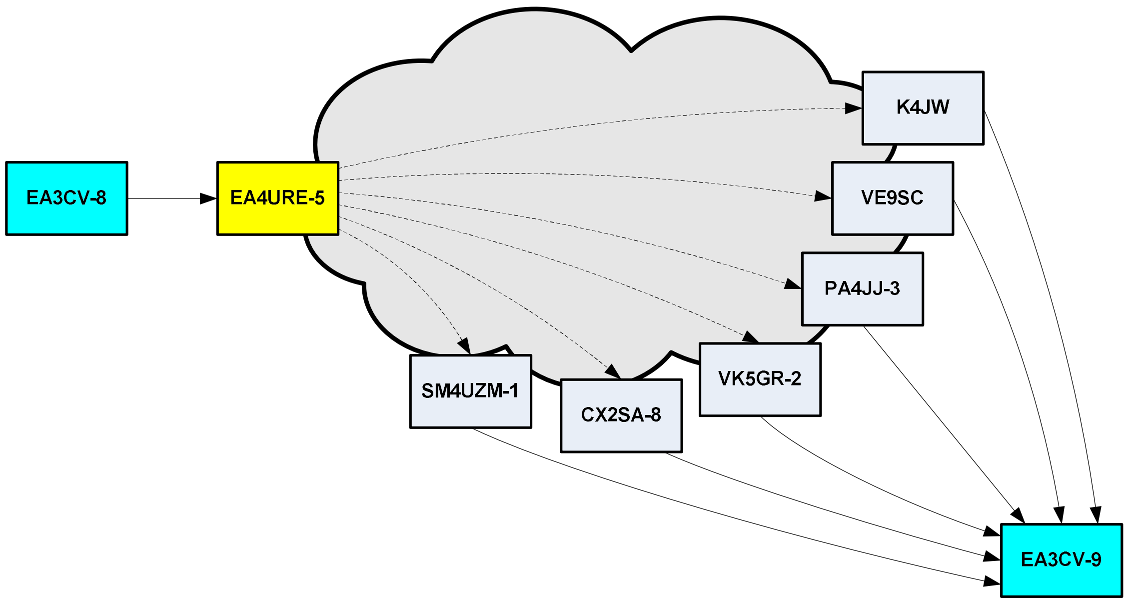
Overall Average Time/Hop: 117.70 ms

SM4UZM-1

Hops	Average Time	Time/Hop
6	942.72 ms	157.12 ms
7	943.00 ms	134.71 ms

Overall Average Time/Hop: 157.07 ms

TEST-1 PC92K



EA3CV 20241209

K4JW

Hops	Average Time	Time/Hop
8	1003.89 ms	125.49 ms
9	1007.64 ms	111.96 ms
10	1060.00 ms	106.00 ms

Overall Average Time/Hop: 121.88 ms

VE9SC

Hops	Average Time	Time/Hop
5	234.33 ms	46.87 ms
6	222.71 ms	37.12 ms
7	554.33 ms	79.19 ms
8	224.00 ms	28.00 ms
10	4251.00 ms	425.10 ms

Overall Average Time/Hop: 38.19 ms

PA4JJ-3

Hops	Average Time	Time/Hop
6	342.67 ms	57.11 ms
7	347.64 ms	49.66 ms
8	340.61 ms	42.58 ms
9	452.33 ms	50.26 ms
10	311.00 ms	31.10 ms

Overall Average Time/Hop: 45.67 ms

VK5GR-2

Hops	Average Time	Time/Hop
7	721.13 ms	103.02 ms
8	721.17 ms	90.15 ms
9	801.75 ms	89.08 ms

Overall Average Time/Hop: 101.70 ms

CX2SA-8

Hops	Average Time	Time/Hop
6	537.72 ms	89.62 ms
7	554.00 ms	79.14 ms
8	509.00 ms	63.62 ms

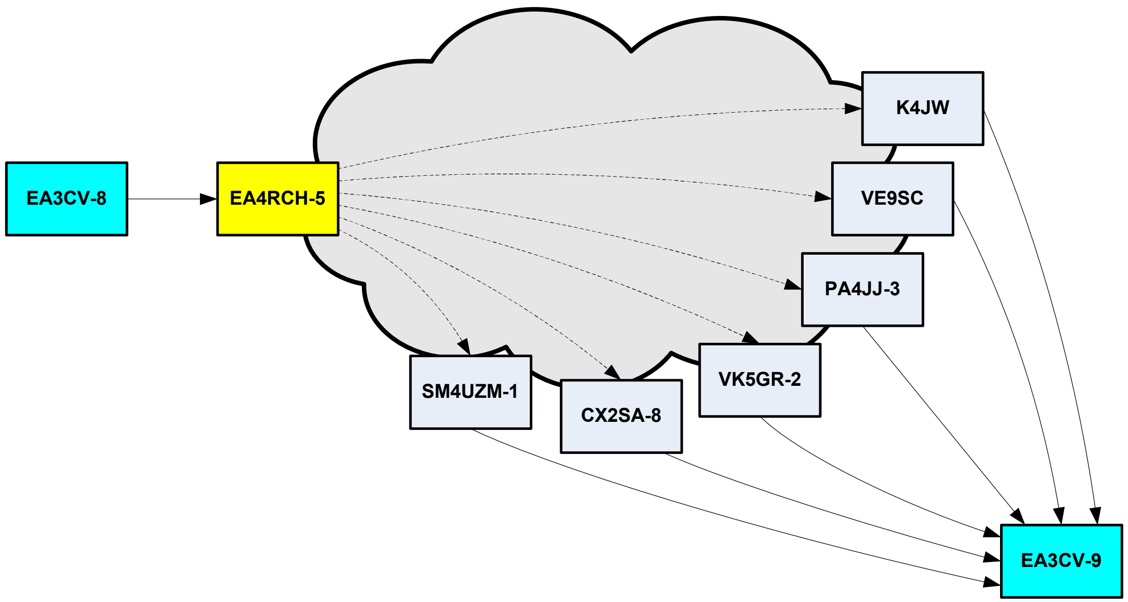
Overall Average Time/Hop: 89.53 ms

SM4UZM-1

Hops	Average Time	Time/Hop
7	322.00 ms	46.00 ms
8	340.52 ms	42.56 ms
9	352.74 ms	39.19 ms
10	351.00 ms	35.10 ms

Overall Average Time/Hop: 42.10 ms

TEST-2 PC92K



EA3CV 20241209

K4JW

Hops	Average Time	Time/Hop
8	1003.89 ms	125.49 ms
9	1007.64 ms	111.96 ms
10	1060.00 ms	106.00 ms

Overall Average Time/Hop: 121.88 ms

VE9SC

Hops	Average Time	Time/Hop
5	234.33 ms	46.87 ms
6	222.71 ms	37.12 ms
7	554.33 ms	79.19 ms
8	224.00 ms	28.00 ms
10	4251.00 ms	425.10 ms

Overall Average Time/Hop: 38.19 ms

PA4JJ-3

Hops	Average Time	Time/Hop
6	342.67 ms	57.11 ms
7	347.64 ms	49.66 ms
8	340.61 ms	42.58 ms
9	452.33 ms	50.26 ms
10	311.00 ms	31.10 ms

Overall Average Time/Hop: 45.67 ms

VK5GR-2

Hops	Average Time	Time/Hop
7	721.13 ms	103.02 ms
8	721.17 ms	90.15 ms
9	801.75 ms	89.08 ms

Overall Average Time/Hop: 101.70 ms

CX2SA-8

Hops	Average Time	Time/Hop
6	537.72 ms	89.62 ms
7	554.00 ms	79.14 ms
8	509.00 ms	63.62 ms

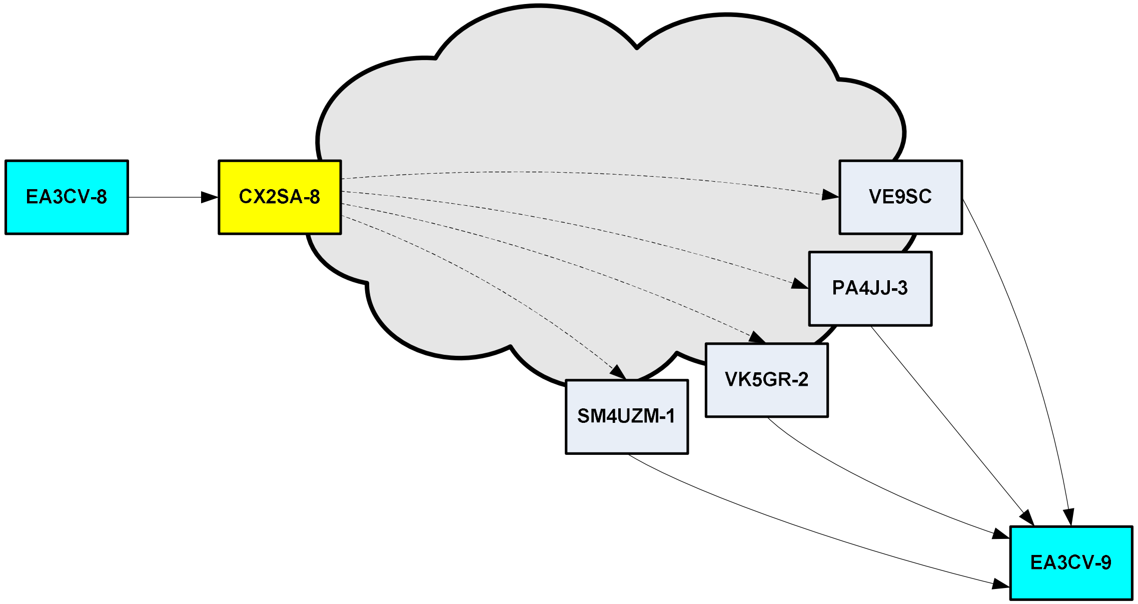
Overall Average Time/Hop: 89.53 ms

SM4UZM-1

Hops	Average Time	Time/Hop
7	322.00 ms	46.00 ms
8	340.52 ms	42.56 ms
9	352.74 ms	39.19 ms
10	351.00 ms	35.10 ms

Overall Average Time/Hop: 42.10 ms

TEST-3 PC92K



VE9SC

Hops	Average Time	Time/Hop
5	398.00 ms	79.60 ms
7	899.50 ms	128.50 ms
8	413.07 ms	51.63 ms
9	1578.67 ms	175.41 ms

Overall Average Time per Hop: 108.79 ms

PA4JJ-3

Hops	Average Time	Time/Hop
5	498.83 ms	99.77 ms
6	398.11 ms	66.35 ms
7	433.73 ms	61.96 ms
8	393.86 ms	49.23 ms

Overall Average Time/Hop: 69.33 ms

VK5GR-2

Hops	Average Time	Time/Hop
5	1383 ms	276.60 ms

Overall Average Time per Hop: 276.60 ms

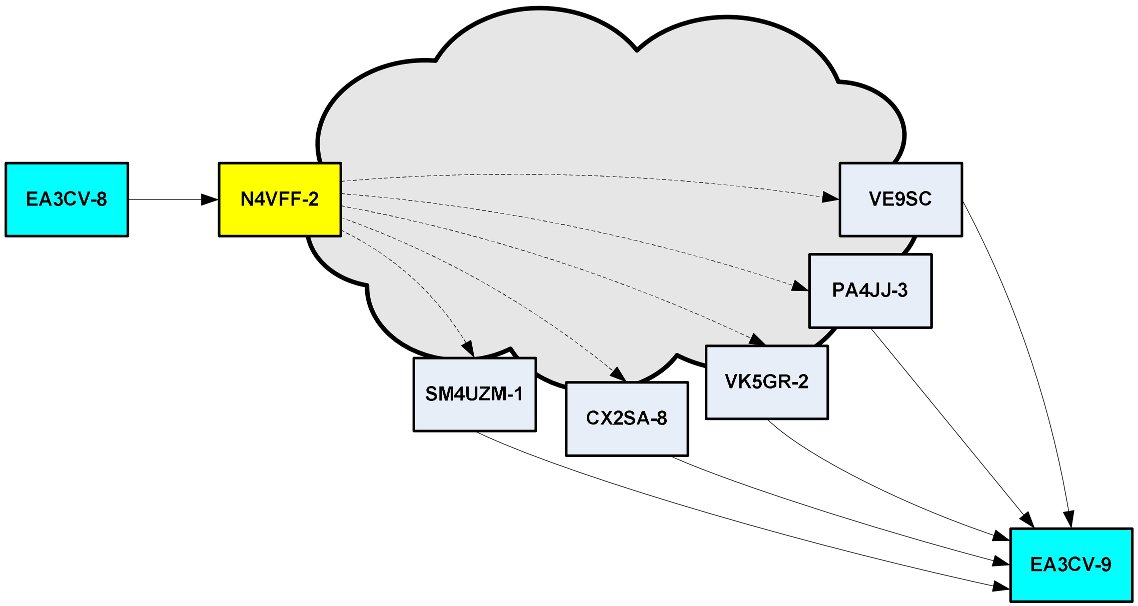
SM4UZM-1

Hops	Average Time	Time/Hop
6	617.77 ms	102.96 ms
8	618.00 ms	77.25 ms
9	591.00 ms	65.67 ms

Overall Average Time per Hop: 81.96 ms

EA3CV 20241209

TEST-4 PC92K



EA3CV 20241209

VE9SC

Time	Hops	Time/Hop
1112 ms	7	158.86 ms

Overall Average Time/Hop: 158.86 ms

PA4JJ-3

Time	Hops	Time/Hop
1167 ms	7	166.71 ms
1112 ms	8	139.00 ms

Overall Average Time/Hop: 152.86 ms

VK5GR-2

Time	Hops	Time/Hop
1121 ms	6	186.83 ms
1120 ms	7	160.05 ms

Overall Average Time/Hop: 173.44 ms

CX2SA-8

Time	Hops	Time/Hop
1392 ms	8	174.10 ms
1418 ms	9	157.56 ms

Overall Average Time/Hop: 165.83 ms

SM4UZM-1

Time	Hops	Time/Hop
472 ms	7	67.43 ms

Overall Average Time/Hop: 67.43 ms