Memo

To
To whom it may concern

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Subject
D-Flow 1D NetCDF-format; CF-1.6 UGRID-1.0/Deltares-0.8

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1 Network1D (map) nc-file

. . .

```
double s1(time, nMeshNodes):
    coordinates = 'mesh1D_node_x mesh1D_node_y'
    location = 'node' // /
    long_name = 'water level'
    mesh = 'mesh1D'   //  this is UGRID location pointing to mesh1D topology
    standard_name = 'sea_surface_height_above_geoid'
    units = 'm'
double u(time, nMeshEdges)
    coordinates = 'mesh1D_edge_x mesh1D_edge_y' // this is CF location sufficient to plot marke
    location = 'edge' // /
    long_name = 'velocity along branch'
    mesh = 'mesh1D'   //  this is UGRID location pointing to mesh1D topology
    standard_name = 'sea_water_speed' // not quite correct because it's not the magnitude,
                                         but signed scalar velocity
    units = 'm s-1'

...
```

2 D-Flow 1D history nc-file

To be added station locations, see for an example the D-Flow FM history file.

```
...

double s1(time=ntimes, stations=nstations);
    coordinates = "station_x station_y"
    long_name = "water level"
    standard_name = "sea_surface_height_above_geoid"
    units = "m"
double u(time=ntimes, stations=nstations);
    coordinates = "station_xu station_yu"
    long_name = "velocity along branch"
    standard_name = "sea_water_speed"
    units = "m s-1"

...
```

Note: The coordinates of the station does not necessarily have the same coordinates as the mesh or network.

3 Example based on Figure 1

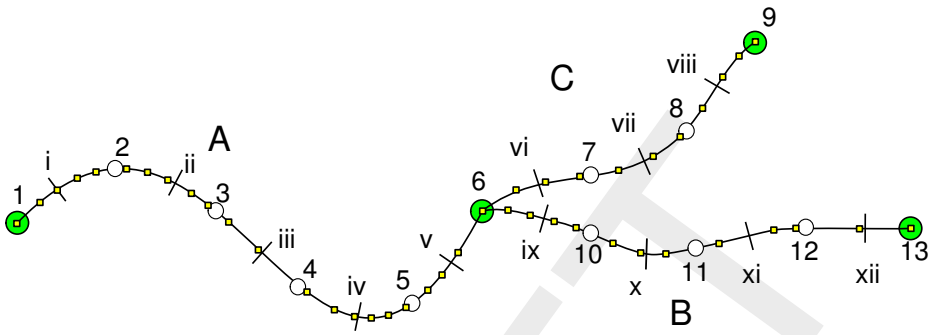

Figure 1: Simple 1D network; 3 branches (A, B, C); 13 nodes (ζ-points, latin numbers), 12 edges (u-points; roman numbers), 44 network nodes (yellow squares)

Dimensions

nNetworkBranches = 3
nNetworkNodes = 4
nBranchPointsTotal = 46
nGeomPoints = 44
nMeshNodes = 13 (13=6+5+4-(3-1); 3 branches are connected to node 6)
nMeshEdges = 12 (12=5+4+3); edges are between ζ-points

3.1 Network nodes

network1D_nodes_x(nNetworkNodes)
`-187.96667, 2195.7333, 4071.4928, 3445.4246`

network1D_nodes_y(nNetworkNodes)
`720.81667, 708.71667, 690.94861, 1540.1838`

network1D_edge_nodes(nNetworkBranches,Two)
```
 1   2
 2   3
 2   4
```

3.2 Geometry

network1D_part_node_count(nNetworkBranches)
`22, 13, 11`

So the branches contain the following geometry points:
Branch A: `1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20`

Branch B: `22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34,`
Branch C: `22, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44`
Note that the node number 22 appear three times in this array.

network1D_geom_x(nNetworkNodes)
`x_1, ..., x_46`

network1D_geom_y(nNetworkNodes)
`y_1, ..., y_46`

4 Numerical discretization

mesh1D_nodes_branch_id(nMeshNodes)
`A, A, A, A, A, A, C, C, C, B, B, B, B`

mesh1D_nodes_branch_offset(nMeshNodes)
`0, 500, 1000, 1500, 2000, 2500` (on branche A, 6 nodes)
`700, 1400, 2100` (on branche B, 4 nodes; without node 6)
`400, 800, 1200, 1600` (on branche C, 3 nodes; without node 6)

5 Example based on Figure 2

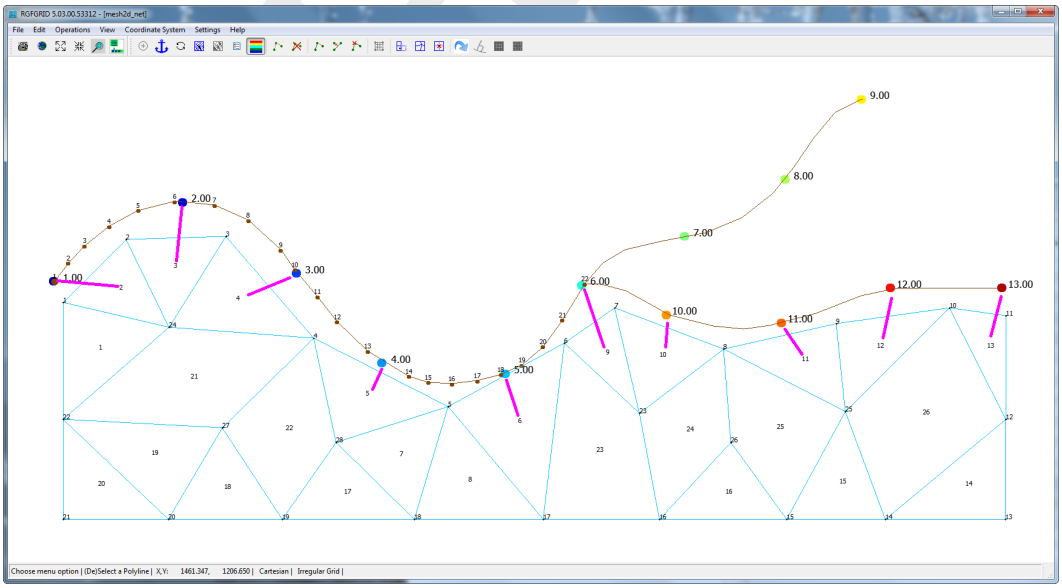

Figure 2: Composite mesh (1D and 2D),
1D Mesh*: coloured dots (=computational 1D mesh), ζ-points; numbered dots, 1d network geometry for branch A (Figure 1).*
2D Mesh*: light blue with node and face numbers.*
1D2D connections are pink coloured.

1D2D-links

1D2D-links are defined between de computational nodes of the 1D Mesh (ζ-points) and the faces of the 2D Mesh (ζ-points). The link table for Figure 2 read:

Table 1: 1D2D Link table based on Figure 2

1d node	2d face
1	2
2	3
3	4
4	5
5	6
6	9
10	10
11	11
12	12
13	13

6 Example of ncdump-file based on Figure 2

```
netcdf ugrid_1d2d_map {
dimensions:
nNetworkBranches = 3 ;
nNetworkNodes = 4 ;
nGeometryNodes = 46 ;
nMesh1DNodes = 13 ;
nMesh1DEdges = 12 ;
max_nMesh2D_face_nodes = 4 ;
nMesh2D_edge = 53 ;
nMesh2D_face = 26 ;
nMesh2D_node = 28 ;
nlinks_1d2d = 10 ;
time = UNLIMITED ; // (2 currently)
Two = 2 ;
variables:
uint network1D ;
network1D:cf_role = "mesh_topology" ;
network1D:edge_dimension = "nNetworkBranches" ;
network1D:edge_geometry = "network1D_geometry" ;
network1D:edge_node_connectivity = "network1D_edge_nodes" ;
network1D:long_name = "Network topology" ;
network1D:node_coordinates = "network1D_nodes_x network1D_nodes_y" ;
network1D:node_dimension = "nNetworkNodes" ;
network1D:topology_dimension = 1 ;
double network1D_nodes_x(nNetworkNodes) ;
network1D_nodes_x:standard_name = "projection_x_coordinate" ;
network1D_nodes_x:long_name = "x coordinates of the network connection nodes" ;
network1D_nodes_x:units = "m" ;
double network1D_nodes_y(nNetworkNodes) ;
network1D_nodes_y:standard_name = "projection_y_coordinate" ;
network1D_nodes_y:long_name = "y coordinates of the network connection nodes" ;
network1D_nodes_y:units = "m" ;
uint network1D_geometry ;
network1D_geometry:geometry_type = "multiline" ;
network1D_geometry:long_name = "1D Geometry" ;
network1D_geometry:node_count = "nGeometryNodes" ;
network1D_geometry:part_node_count = "network1D_part_node_count" ;
network1D_geometry:node_coordinates = "network1D_geom_x network1D_geom_y" ;
uint network1D_edge_nodes(nNetworkBranches, Two) ;
network1D_edge_nodes:cf_role = "edge_node_connectivity" ;
network1D_edge_nodes:long_name = "start and end nodes of each branch in the network" ;
network1D_edge_nodes:start_index = 1 ;
uint network1D_part_node_count(nNetworkBranches) ;
network1D_part_node_count:long_name = "number of geometry nodes per branch" ;
double network1D_geom_x(nGeometryNodes) ;
network1D_geom_x:cf_role = "geometry_x_node" ;
network1D_geom_x:standard_name = "projection_x_coordinate" ;
network1D_geom_x:long_name = "x coordinates of the branch geometries" ;
network1D_geom_x:units = "m" ;
double network1D_geom_y(nGeometryNodes) ;
network1D_geom_y:cf_role = "geometry_y_node" ;
network1D_geom_y:standard_name = "projection_y_coordinate" ;
network1D_geom_y:long_name = "y coordinates of the branch geometries" ;
network1D_geom_y:units = "m" ;
uint mesh1D ;
```

```
mesh1D:cf_role = "mesh_topology" ;
mesh1D:coordinate_space = "network1D" ;
mesh1D:edge_dimension = "nmesh1DEdges" ;
mesh1D:edge_node_connectivity = "mesh1D_edge_nodes" ;
mesh1D:long_name = "Mesh 1D" ;
mesh1D:node_coordinates = "mesh1D_nodes_branch_id mesh1D_nodes_branch_offset" ;
mesh1D:node_dimension = "nmesh1DNodes" ;
mesh1D:topology_dimension = 1 ;
uint mesh1D_nodes_branch_id(nMesh1DNodes) ;
mesh1D_nodes_branch_id:cf_role = "feature_index" ;
mesh1D_nodes_branch_id:long_name = "number of branch on which node is located" ;
double mesh1D_nodes_branch_offset(nMesh1DNodes) ;
mesh1D_nodes_branch_offset:cf_role = "coordinate_on_feature" ;
mesh1D_nodes_branch_offset:long_name = "offset along the branch at which the node is located
mesh1D_nodes_branch_offset:units = "m" ;
uint Mesh2D ;
Mesh2D:cf_role = "mesh_topology" ;
Mesh2D:edge_coordinates = "Mesh2D_edge_x Mesh2D_edge_y" ;
Mesh2D:edge_dimension = "nMesh2D_edge" ;
Mesh2D:edge_face_connectivity = "Mesh2D_edge_faces" ;
Mesh2D:edge_node_connectivity = "Mesh2D_edge_nodes" ;
Mesh2D:face_coordinates = "Mesh2D_face_x Mesh2D_face_y" ;
Mesh2D:face_dimension = "nMesh2D_face" ;
Mesh2D:face_edge_connectivity = "Mesh2D_face_edges" ;
Mesh2D:face_face_connectivity = "Mesh2D_face_face" ;
Mesh2D:face_node_connectivity = "Mesh2D_face_nodes" ;
Mesh2D:long_name = "Mesh 2D" ;
Mesh2D:max_face_nodes_dimension = "max_nMeshFaceNodes" ;
Mesh2D:node_coordinates = "Mesh2D_node_x Mesh2D_node_y" ;
Mesh2D:node_dimension = "nMesh2D_node" ;
Mesh2D:topology_dimension = 2 ;
double Mesh2D_node_x(nMesh2D_node) ;
Mesh2D_node_x:standard_name = "projection_x_coordinate" ;
Mesh2D_node_x:units = "m" ;
double Mesh2D_node_y(nMesh2D_node) ;
Mesh2D_node_y:standard_name = "projection_y_coordinate" ;
Mesh2D_node_y:units = "m" ;
double Mesh2D_edge_x(nMesh2D_edge) ;
Mesh2D_edge_x:standard_name = "projection_x_coordinate" ;
Mesh2D_edge_x:units = "m" ;
double Mesh2D_edge_y(nMesh2D_edge) ;
Mesh2D_edge_y:standard_name = "projection_y_coordinate" ;
Mesh2D_edge_y:units = "m" ;
double Mesh2D_edge_nodes(nMesh2D_edge, Two) ;
Mesh2D_edge_nodes:cf_role = "edge_node_connectivity" ;
Mesh2D_edge_nodes:long_name = "maps every edge to the two nodes that it connects" ;
Mesh2D_edge_nodes:start_index = 1 ;
double Mesh2D_face_nodes(nMesh2D_face, max_nMesh2D_face_nodes) ;
Mesh2D_face_nodes:_FillValue = 0. ;
Mesh2D_face_nodes:cf_role = "face_node_connectivity" ;
Mesh2D_face_nodes:long_name = "maps every face to the nodes that it defines" ;
Mesh2D_face_nodes:start_index = 1 ;
uint composite_mesh ;
composite_mesh:cf_role = "mesh_topology_parent" ;
composite_mesh:meshes = "mesh1D mesh2D" ;
composite_mesh:mesh_contact = "link1d2d" ;
uint link1d2d(nlinks_1d2d, Two) ;
link1d2d:cf_role = "mesh_topology_contact" ;
```

```
link1d2d:contact = "mesh1D:node mesh2D:face" ;
link1d2d:start_index = 1 ;
double time(time) ;
time:standard_time = "time" ;
time:units = "seconds since 2017-01-01 00:00:00" ;
double s1_1d(time, nMesh1DNodes) ;
s1_1d:location = "node" ;
s1_1d:long_name = "water level" ;
s1_1d:mesh = "mesh1D" ;
s1_1d:standard_name = "sea_surface_height_above_geoid" ;
s1_1d:units = "m" ;
double u_1d(time, nMesh1DEdges) ;
u_1d:location = "edge" ;
u_1d:long_name = "velocity along branch" ;
u_1d:mesh = "mesh1D" ;
u_1d:standard_name = "sea_water_speed" ;
u_1d:units = "m s-1" ;
double s1_2d(time, nMesh2D_face) ;
s1_2d:coordinates = "Mesh2D_face_x Mesh2D_face_y" ;
s1_2d:location = "face" ;
s1_2d:long_name = "water level" ;
s1_2d:mesh = "Mesh2D" ;
s1_2d:standard_name = "sea_surface_height_above_geoid" ;
s1_2d:units = "m" ;
double u_2d(time, nMesh2D_edge) ;
u_2d:coordinates = "Mesh2D_edge_x Mesh2D_edge_y" ;
u_2d:location = "edge" ;
u_2d:long_name = "normal velocity at edge" ;
u_2d:mesh = "Mesh2D" ;
u_2d:standard_name = "sea_water_speed" ;
u_2d:units = "m s-1" ;

// global attributes:
:Conventions = "CF-1.8 UGRID-1.0/Deltares-0.9" ;
:history = "Created on 2017-11-18 20:50:29.618000 D-Flow 1D, D-Flow FM. 1D2D coupling" ;
:institution = "Deltares" ;
:reference = "http://www.deltares.nl" ;
:source = "Python program to test layout of a D-Flow 1D, D-Flow FM" ;
data:

network1D = _ ;

network1D_nodes_x = -187.96667, 2195.7333, 4071.4928, 3445.4246 ;

network1D_nodes_y = 720.81667, 708.71667, 690.94861, 1540.1838 ;

network1D_geometry = _ ;

network1D_edge_nodes =
1, 2,
2, 3,
2, 4 ;

network1D_part_node_count = 22, 13, 11 ;

network1D_geom_x = -187.96667, -127.96887, -53.84786, 56.174104, 187.13333,
352.5, 529.96667, 683.23333, 828.43333, 892.96667, 993.8, 1082.5333,
1219.6667, 1405.2, 1492.2591, 1598.5306, 1712.2164, 1818.4835, 1912.3747,
```

```
2007.9644, 2094.9, 2195.7333, 2195.7333, 2269.2456, 2381.5612, 2460.2412,
2577.8276, 2774.8643, 2911.5187, 3029.1051, 3235.6759, 3438.7319,
3582.0791, 3817.2519, 4071.4928, 2195.7333, 2275.9165, 2377.6129,
2539.6914, 2739.9061, 2901.9847, 3041.8172, 3140.3355, 3226.4949,
3321.8353, 3445.4246 ;

network1D_geom_y = 720.81667, 802.67261, 879.96131, 968.25292, 1039.45,
1079.7833, 1063.65, 995.08333, 861.98333, 773.25, 652.25, 539.31667,
406.21667, 293.28333, 265.90693, 260.14026, 273.32123, 301.64228,
343.82527, 427.37378, 547.38333, 708.71667, 708.71667, 705.99709,
676.04627, 633.74441, 567.00618, 519.33601, 506.62397, 522.51403,
576.54021, 655.98306, 684.59259, 690.94861, 690.94861, 708.71667,
802.179, 862.56121, 900.69734, 938.83347, 1005.5717, 1116.8021,
1237.5665, 1367.1587, 1480.1547, 1540.1838 ;

mesh1D = _ ;

mesh1D_nodes_branch_id = 1, 1, 1, 1, 1, 1, 3, 3, 3, 2, 2, 2, 2 ;

mesh1D_nodes_branch_offset = 0, 500, 1000, 1500, 2000, 2500, 700, 1400,
2100, 400, 800, 1200, 1600 ;

Mesh2D = _ ;

Mesh2D_node_x = -150, 133.043016423945, 581.589811881954, 976.640200542219,
1581.56110817825, 2104.17985151006, 2330.51080334667, 2820.20868095679,
3326.36699142775, 3836.64041011393, 4091.3328, 4091.0588, 4087.6891,
3547.526, 3104.2863, 2530.6819, 2009.2233, 1428.1695, 835.9416,
321.93246, -150, -150, 2441.32387428041, 326.036595922787,
3368.4335297957, 2852.91575366228, 564.605213864027, 1077.48494483683 ;

Mesh2D_node_y = 625.39432, 908.781962364921, 921.127287010554,
464.350275122123, 155.717158981291, 443.774734046067, 600.148846224089,
414.968976539589, 530.1920065655, 600.148846224089, 565.79906,
99.9999999999999, -350, -350, -350, -350, -350, -350, -350, -350,
99.9999999999999, 125.838619350021, 513.501770748115, 134.310966738994,
-5.00908866931604, 62.2847173147688, -3.38148493072237 ;

Mesh2D_edge_x = 3963.98660505697, 3963.84960505697, 4091.1958,
2217.34532742836, 2272.75186289524, 2385.91733881354, 2630.7662776186,
2575.35974215173, 2056.70157575503, -8.4784917880275, 88.0182979613934,
229.539806173366, 3325.90615, 3457.97976489785, 3236.35991489785,
2836.56221730954, 4089.37395, 3819.2924, 3817.60755, 357.316414152949,
453.81320390237, -150, 85.96623, 85.96623, 2978.60102683114,
2691.79882683114, 2817.4841, 2486.00288714021, 3347.40026061173,
3073.28783619227, 3094.32110537625, 578.93703, 700.273406932013,
443.268836932014, 2269.9526, -150, 88.0182979613934, 207.302606932014,
956.713272418414, 651.338398232503, 779.115006212086, 1718.6964,
1795.39220408913, 1504.86530408912, 1132.05555, 1252.82722241841,
1329.52302650754, 1027.06257268952, 770.622707203123, 1279.10065436023,
1842.87047984415, 3602.53696995482, 3581.50370077084 ;

Mesh2D_edge_y = 582.973953112045, 350.074423112044, 332.89953,
521.961790135078, 284.806676698044, 362.993732787055, 270.403797944805,
507.558911381839, 46.8873670230335, 767.088141182461, 569.448045374058,
711.141866556518, -350, -107.844516630503, -107.844516630503,
204.979943935137, -125, -125, -350, 914.954624687738, 717.314528879334,
-125, -350, -125, -177.504544334658, -177.504544334658, -350,
```

```
-112.080690324989, 332.251486652247, 472.580491552545, 274.639971639292,
-350, -143.857641342616, -143.857641342616, -350, 362.69716,
306.750885374057, 81.1423586573843, -176.690742465361, 488.926022935119,
692.738781066338, -350, -97.1414205093546, -97.1414205093546, -350,
-176.690742465361, 76.1678370252842, 230.4843950957, 263.317496218446,
310.033717051707, 299.745946513679, 367.229906481542, 565.170426394795 ;

Mesh2D_edge_nodes =
11, 10,
10, 12,
12, 11,
7, 6,
6, 23,
23, 7,
23, 8,
8, 7,
6, 17,
2, 1,
1, 24,
24, 2,
15, 14,
14, 25,
25, 15,
26, 8,
13, 12,
12, 14,
14, 13,
3, 2,
24, 3,
22, 21,
21, 20,
20, 22,
26, 15,
26, 16,
16, 15,
23, 16,
25, 9,
9, 8,
8, 25,
20, 19,
19, 27,
27, 20,
17, 16,
1, 22,
22, 24,
27, 22,
19, 28,
24, 4,
4, 3,
18, 17,
17, 5,
5, 18,
19, 18,
18, 28,
5, 28,
28, 4,
4, 27,
5, 4,
```

```
6, 5,
25, 10,
10, 9 ;

Mesh2D_face_nodes =
1, 22, 24, _,
1, 24, 2, _,
2, 24, 3, _,
3, 24, 4, _,
4, 28, 5, _,
5, 17, 6, _,
5, 28, 18, _,
5, 18, 17, _,
6, 23, 7, _,
7, 23, 8, _,
8, 25, 9, _,
9, 25, 10, _,
10, 12, 11, _,
12, 14, 13, _,
14, 25, 15, _,
15, 26, 16, _,
18, 28, 19, _,
19, 27, 20, _,
20, 27, 22, _,
20, 22, 21, _,
4, 24, 22, 27,
4, 27, 19, 28,
6, 17, 16, 23,
8, 23, 16, 26,
8, 26, 15, 25,
10, 25, 14, 12 ;

composite_mesh = _ ;

link1d2d =
1, 2,
2, 3,
3, 4,
4, 5,
5, 6,
6, 9,
10, 10,
11, 11,
12, 12,
13, 13 ;

time = 60, 120 ;

s1_1d =
1, 1.33333333333333, 1.66666666666667, 2, 2.33333333333333,
2.66666666666667, 3, 3.33333333333333, 3.66666666666667, 4,
4.33333333333333, 4.66666666666667, 5,
3, 3.33333333333333, 3.66666666666667, 4, 4.33333333333333,
4.66666666666667, 5, 5.33333333333333, 5.66666666666667, 6,
6.33333333333333, 6.66666666666667, 7 ;

u_1d =
1, 1.36363636363636, 1.72727272727273, 2.09090909090909, 2.45454545454545,
```

```
2.81818181818182, 3.18181818181818, 3.54545454545455, 3.90909090909091,
4.27272727272727, 4.63636363636364, 5,
3, 3.36363636363636, 3.72727272727273, 4.09090909090909, 4.45454545454546,
4.81818181818182, 5.18181818181818, 5.54545454545455, 5.90909090909091,
6.27272727272727, 6.63636363636364, 7 ;

s1_2d =
2, 2.16, 2.32, 2.48, 2.64, 2.8, 2.96, 3.12, 3.28, 3.44, 3.6, 3.76, 3.92,
4.08, 4.24, 4.4, 4.56, 4.72, 4.88, 5.04, 5.2, 5.36, 5.52, 5.68, 5.84, 6,
4, 4.16, 4.32, 4.48, 4.64, 4.8, 4.96, 5.12, 5.28, 5.44, 5.6, 5.76, 5.92,
6.08, 6.24, 6.4, 6.56, 6.72, 6.88, 7.04, 7.2, 7.36, 7.52, 7.68, 7.84, 8 ;

u_2d =
2, 2.07692307692308, 2.15384615384615, 2.23076923076923, 2.30769230769231,
2.38461538461538, 2.46153846153846, 2.53846153846154, 2.61538461538462,
2.69230769230769, 2.76923076923077, 2.84615384615385, 2.92307692307692,
3, 3.07692307692308, 3.15384615384615, 3.23076923076923,
3.30769230769231, 3.38461538461538, 3.46153846153846, 3.53846153846154,
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