GTNA

A Framework for the Graph-Theoretic Network Analysis

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GTNA

Graph-Theoretic Network Analyzer

Outline

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1. Introduction
2. Modules and Workflow
3. Available Networks
4. Available Metrics
5. Extension
6. Evaluation
7. Summary and Outlook

1. Introduction

Motivation, Our Approach and Requirements

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Motivation

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- Importance of complex networks rises
- Need for analysis and evaluation
- Simulation research tool of choice
- BUT: credibility of the results decreases

"... less than 15% of the published MobiHoc papers are repeatable."

Kurkowski et al. - MANET Simulation Studies: The Incredibles, 2006

Main Objectives

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- Many different networks and metrics
- Graph-theoretic analysis of complex networks
- Need for an analysis framework
- Plugin interface for metrics and network generators

Requirements

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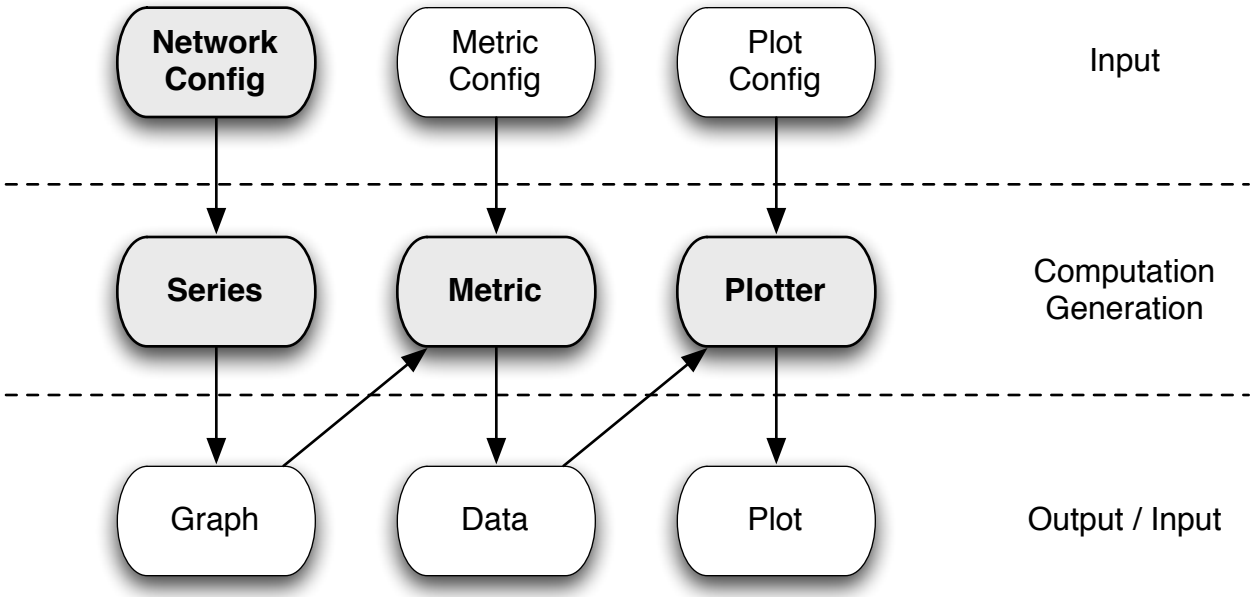
1. Extensability
2. Run on regular desktop computers
3. Evaluate networks with > 20.000 nodes
4. Require less than 2 GB of memory

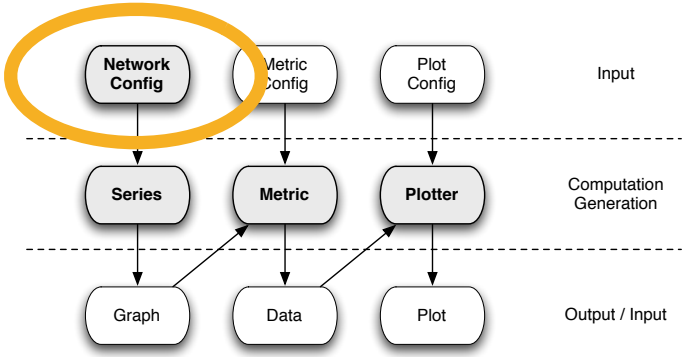
2. Modules and Workflow

The four Modules and how they build GTNA



Network Config

- Interface: *gtna.network.Network*
  1. Set of parameters
  2. Constructor
  3. Graph generation
     - E.g. CAN(nodes, dimensions, realities)

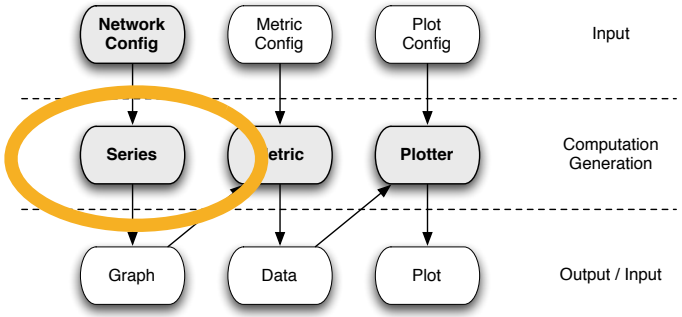


Series

- Implementation: *gtna.data.Series*
- Aggregates several simulation runs
  - Instances of the same network config
  - Averages + confidence intervals
- Input

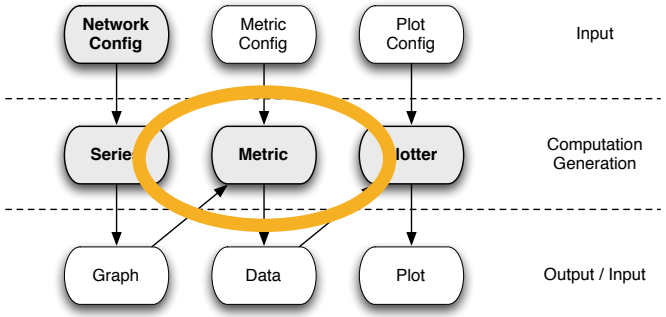
  a. Generated network topology

  b. Imported available traces



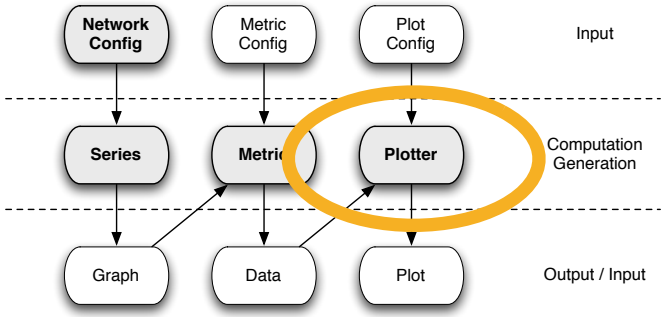
Metric

- Interface: *gtna.metrics.Metric*
  1. Sub-metric attributes
  2. Constructor
  3. Computation
  4. Output generation
- Multi-scalar metrics
  - Array of values for each graph
- Single-scalar metrics
  - Single value for each graph

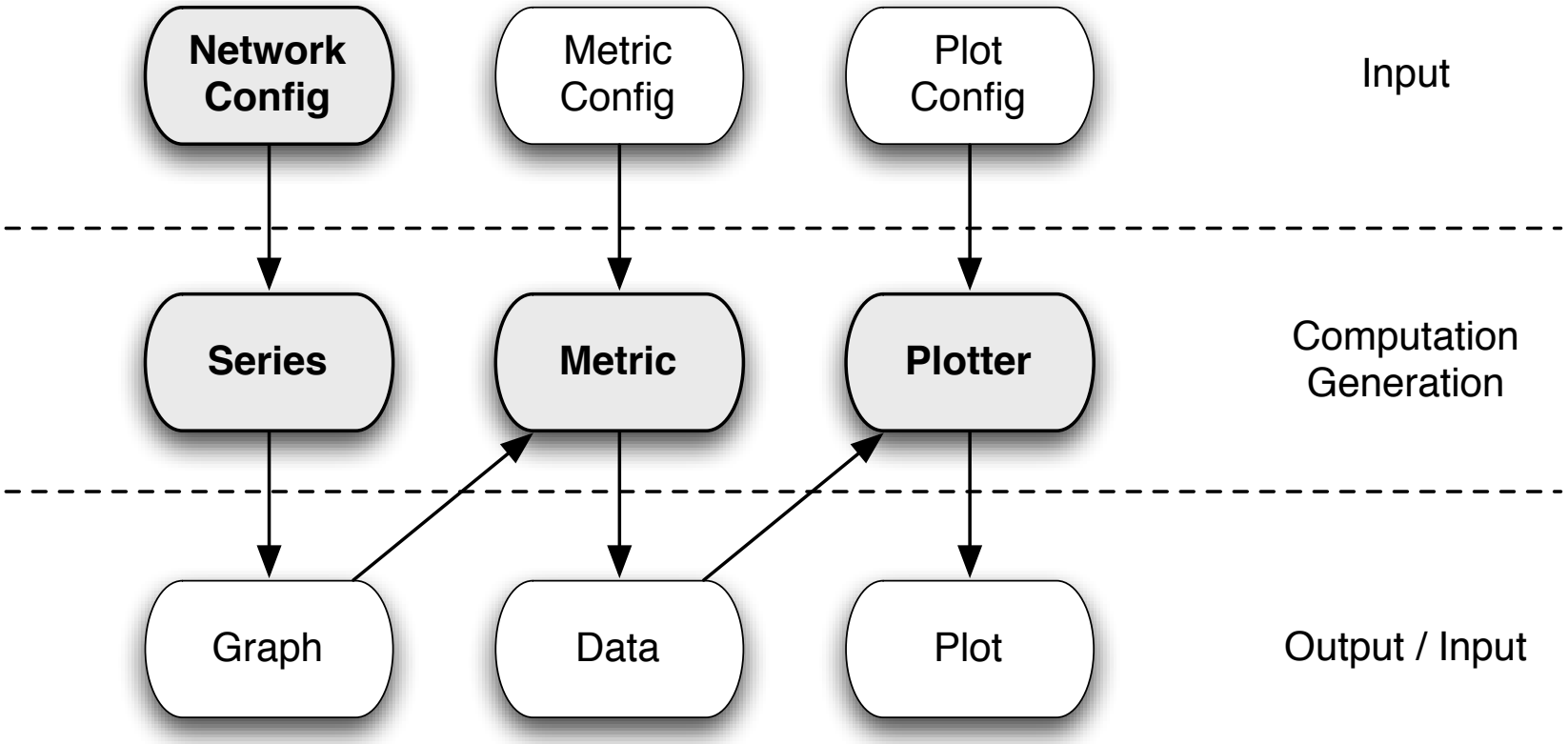


Plotter

- Implementation: *gtna.plot.Plot*
  - Uses *gtna.plot.GNUPlot*
- Plot types
  - Multi, Single, byEdges
- Combination of
  - Multiple metrics
  - Different configuration
  - Different networks



Workflow


Network Config
Metric Config
Plot Config
Input
Series
Metric
Plotter
Computation Generation
Graph
Data
Plot
Output / Input

Instantiating a Network Config

```
Network can_2_1 = new CAN(100, 2, 1);
Network can_3_1 = new CAN(100, 3, 1);
Network can_4_1 = new CAN(100, 4, 1);
Network[] can_x_1 =
  new Network[]{ can_2_1, can_3_1, can_4_1 };

Network can_2_1 = new CAN(100, 2, 1);
Network can_2_2 = new CAN(100, 2, 2);
Network can_2_3 = new CAN(100, 2, 3);
Network[] can_2_x =
  new Network[]{ can_2_1, can_2_2, can_2_3 };

Network can_100 = new CAN(100, 2, 1);
Network can_200 = new CAN(200, 2, 1);
Network can_300 = new CAN(300, 2, 1);
Network can_400 = new CAN(400, 2, 1);
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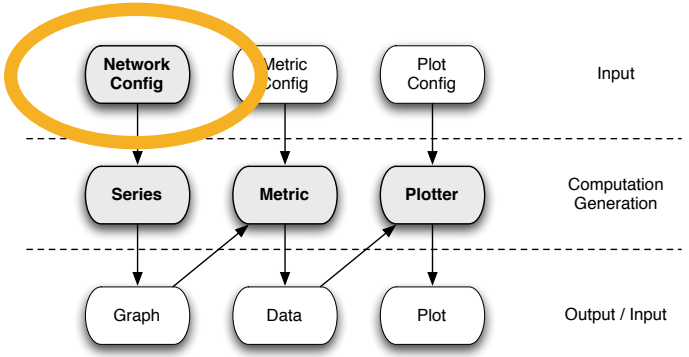

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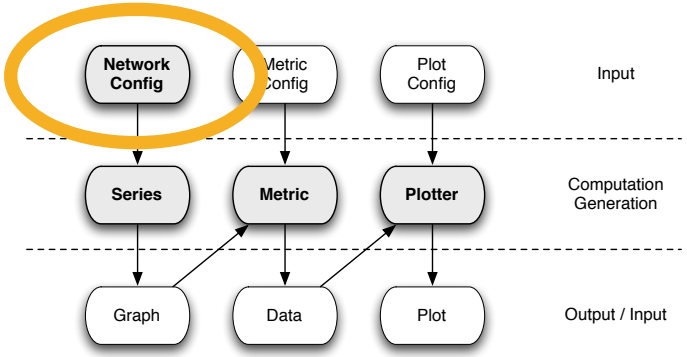

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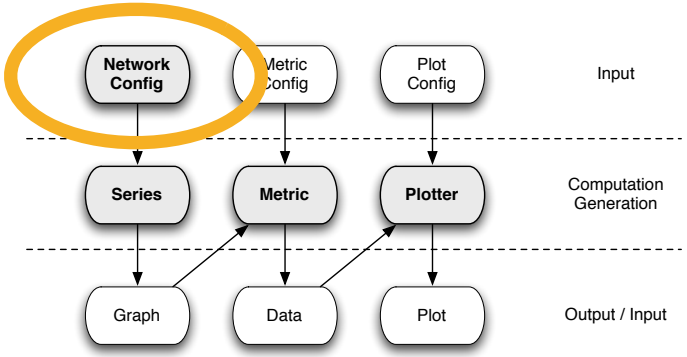

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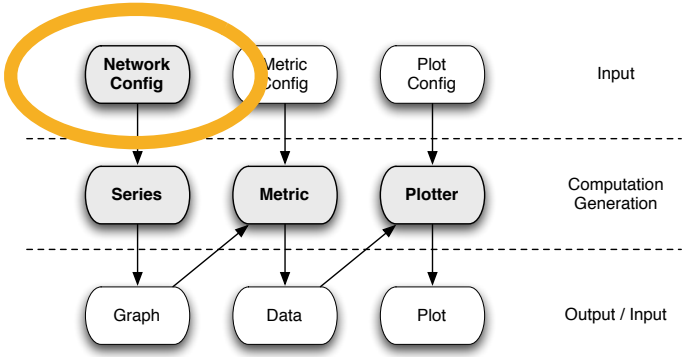

Generating a Series

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Network[] can_2_x =
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Network[] can_x =
  new Network[]{ can_100, can_200, can_300, can_400 };

Series[] s_can_x_1 = Series.generate(can_x_1, 20);
Series[] s_can_2_x = Series.generate(can_2_x, 20);
Series[] s_can_x = Series.generate(can_x, 20);
```

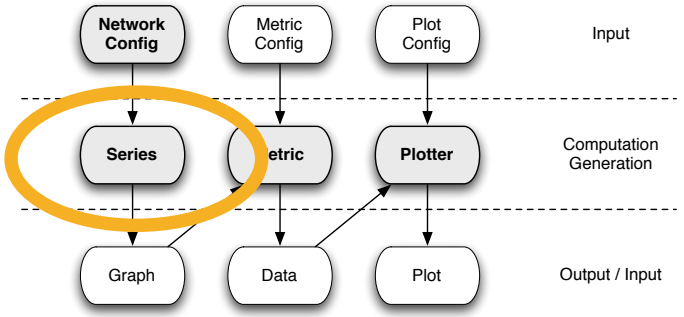

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Network[] can_x =
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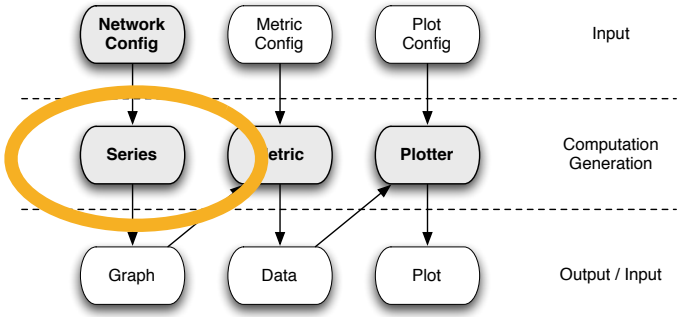
Series[] s_can_x_1 = Series.generate(can_x_1, 20);
Series[] s_can_2_x = Series.generate(can_2_x, 20);
Series[] s_can_x = Series.generate(can_x, 20);
```



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Series[] s_can_x_1 = Series.generate(can_x_1, 20);
Series[] s_can_2_x = Series.generate(can_2_x, 20);
Series[] s_can_x = Series.generate(can_x, 20);
```
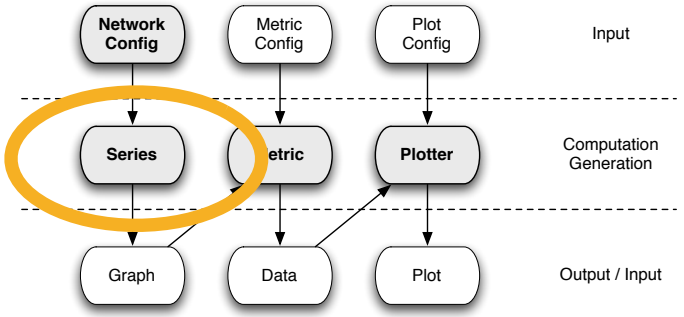
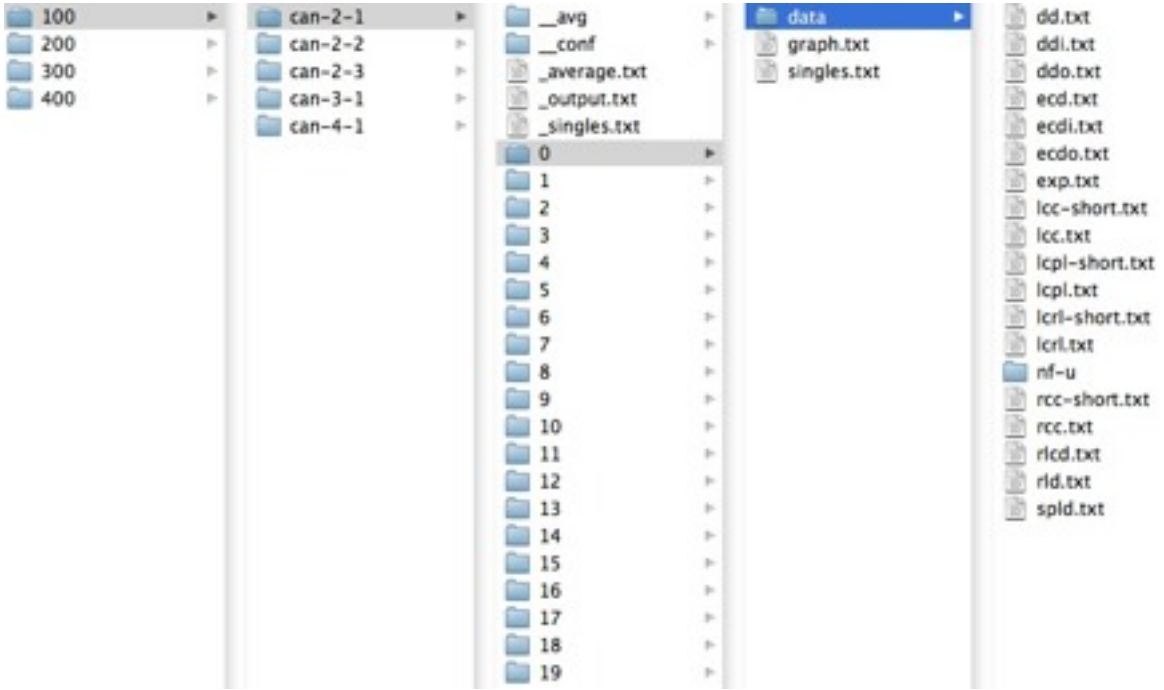
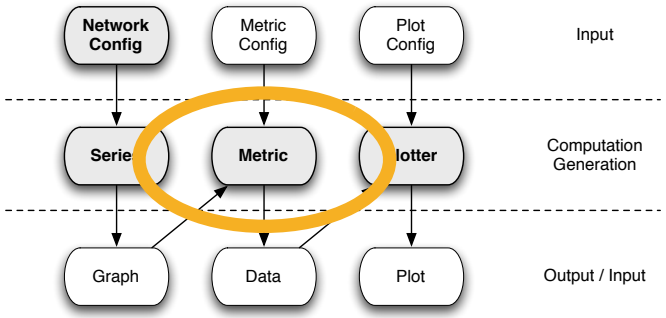



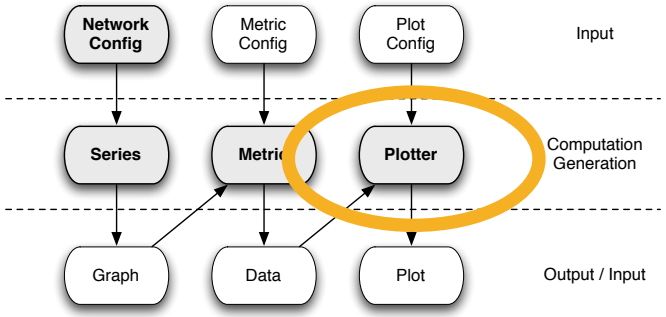
Data Generation





Plotting the Results

```
Series[] s_can_x_1 = Series.get(can_x_1);
Series[] s_can_2_x = Series.get(can_2_x);
Series[] s_can_x = Series.get(can_x);

Plot.allMulti(s_can_x_1, "./can-dimensions/");
Plot.allMulti(s_can_2_x, "./can-realities/");

Plot.allSingle(s_can_x_1, "./can-dimensions-singles/");
Plot.allSingle(s_can_2_x, "./can-realities-singles/");
Plot.allSingle(s_can_x, "./can-nodes-singles/");

Series[][] s_all = new Series[][]{
  s_can_x_1, s_can_2_x };

Plot.allSingleByEdges(s_all, "./can-by-edges/");
```



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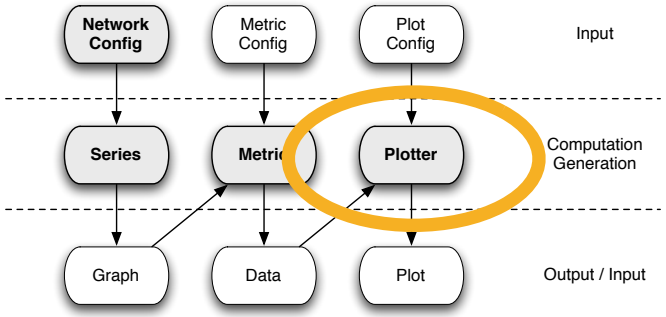

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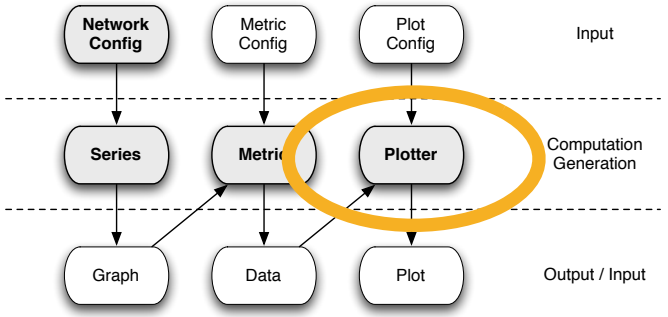
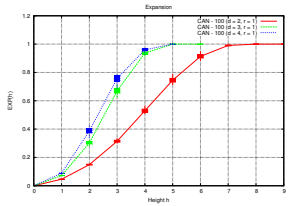
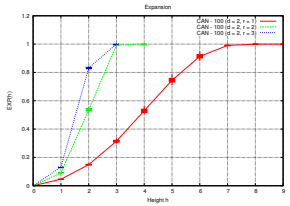
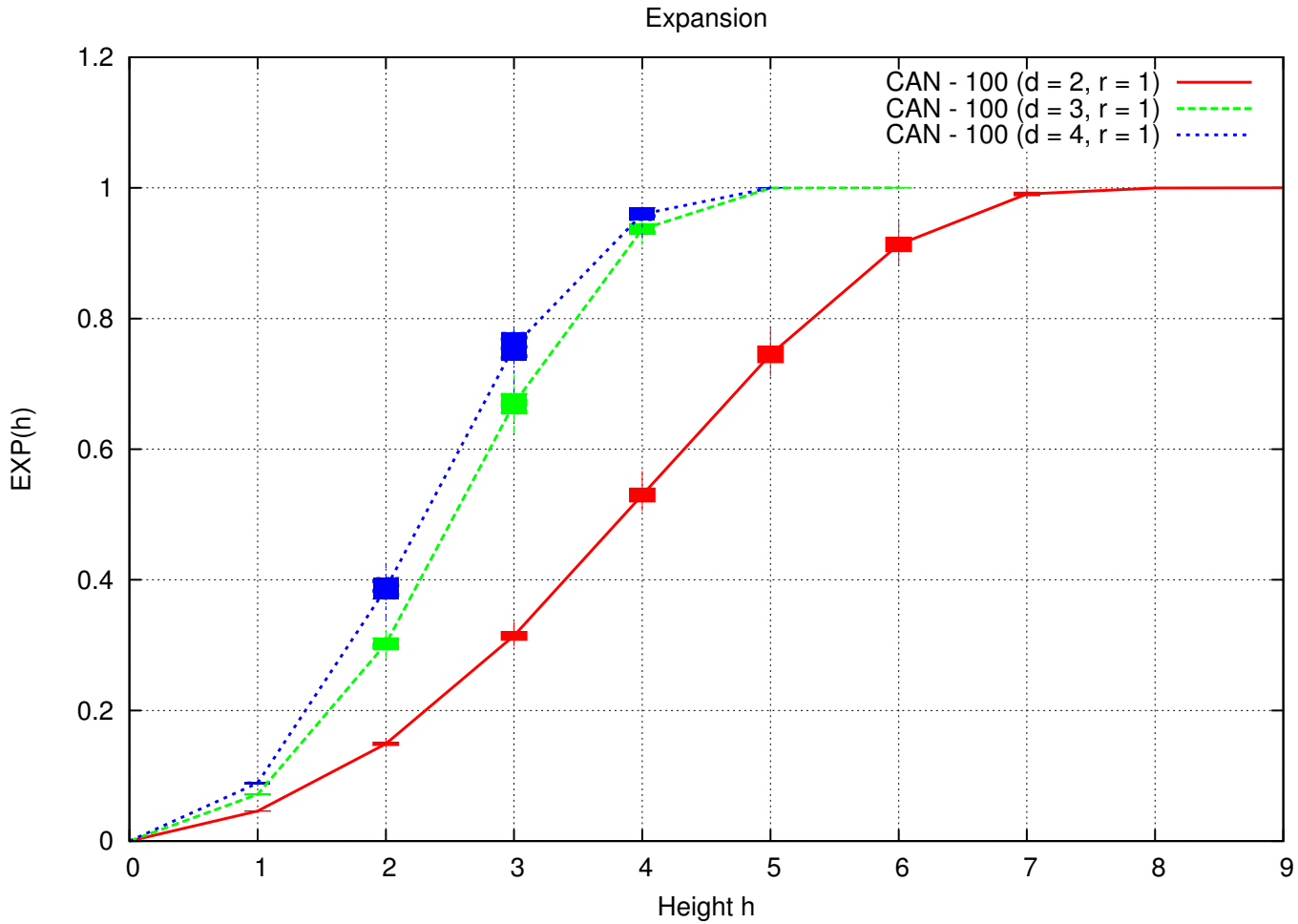
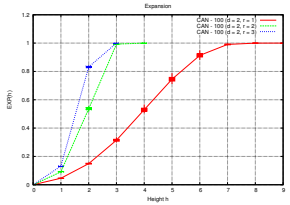






Plotting the Results





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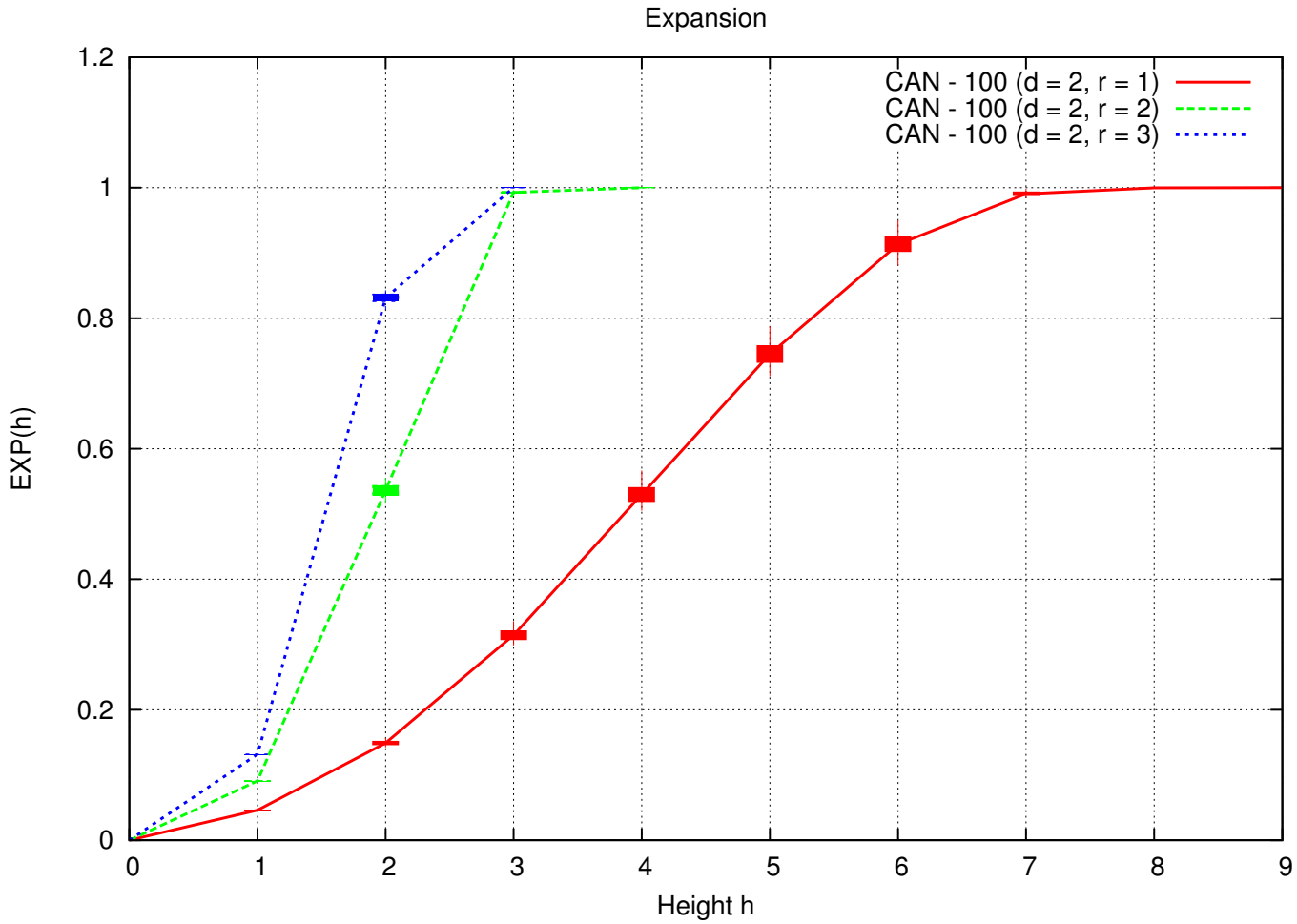

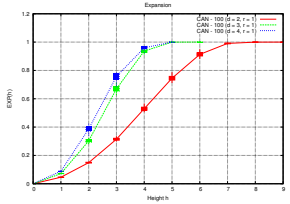

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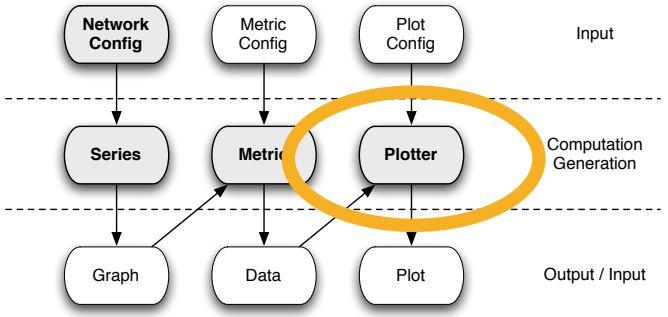

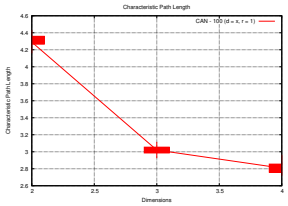

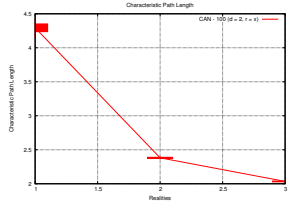

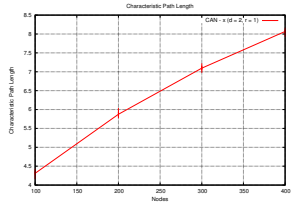

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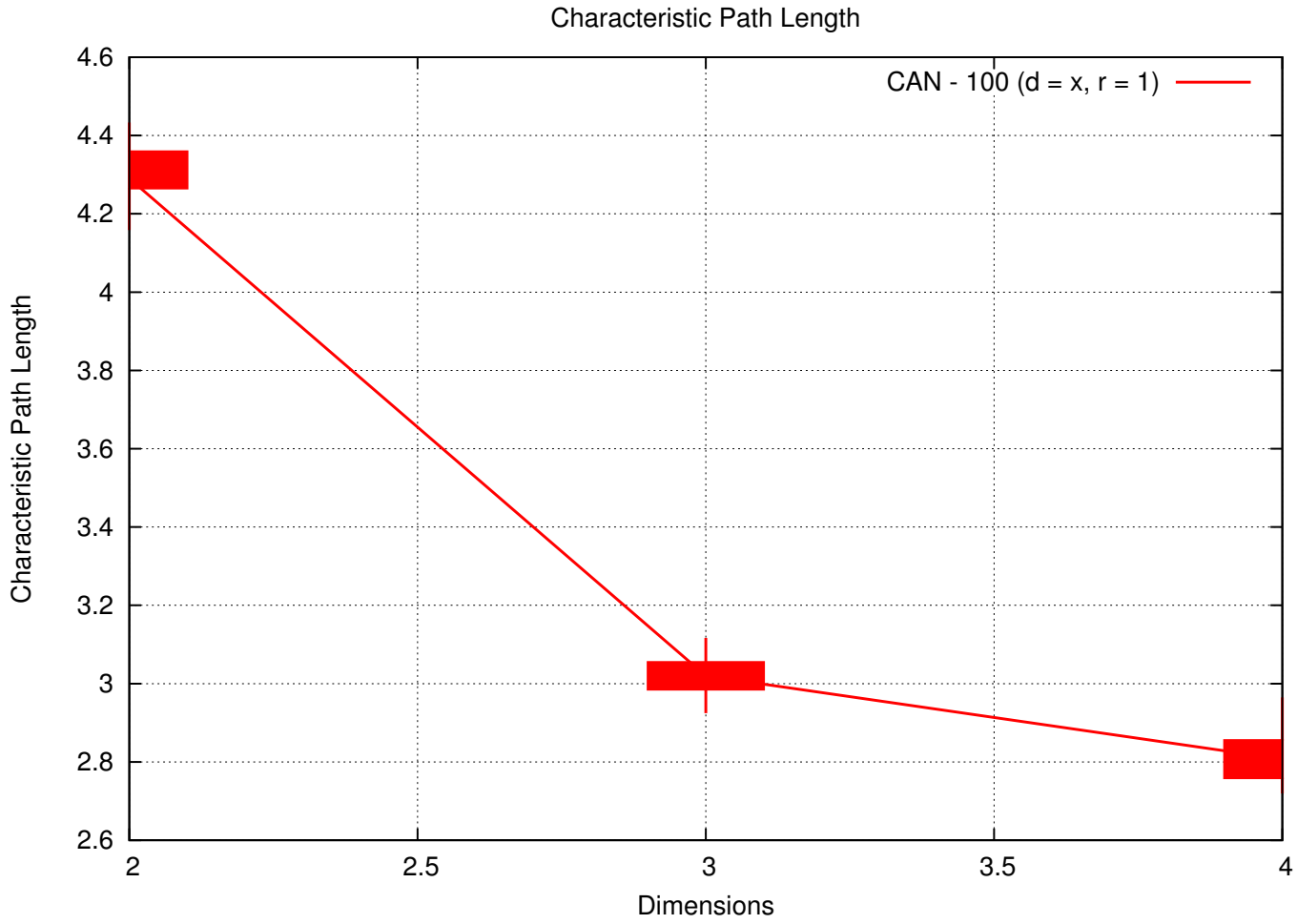

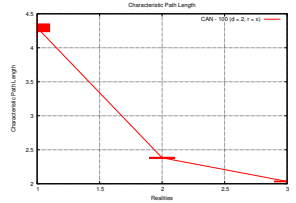

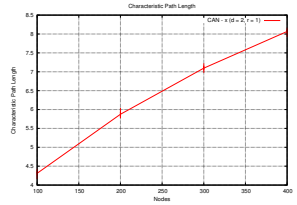

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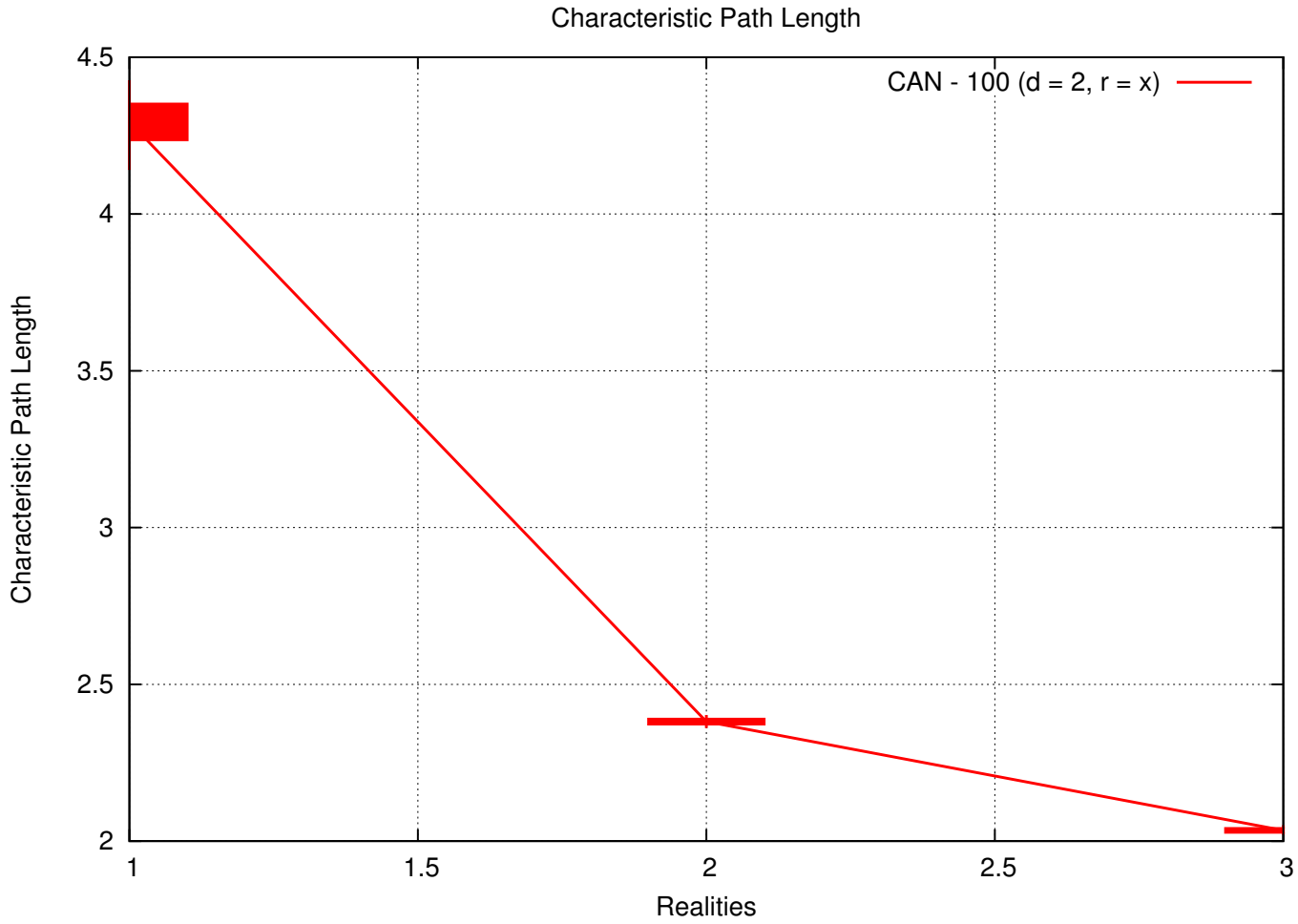

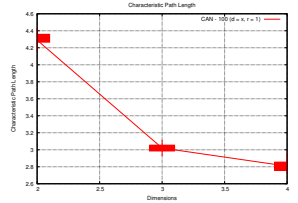

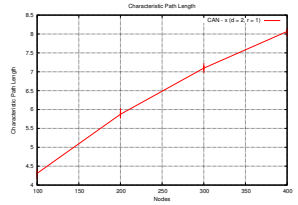

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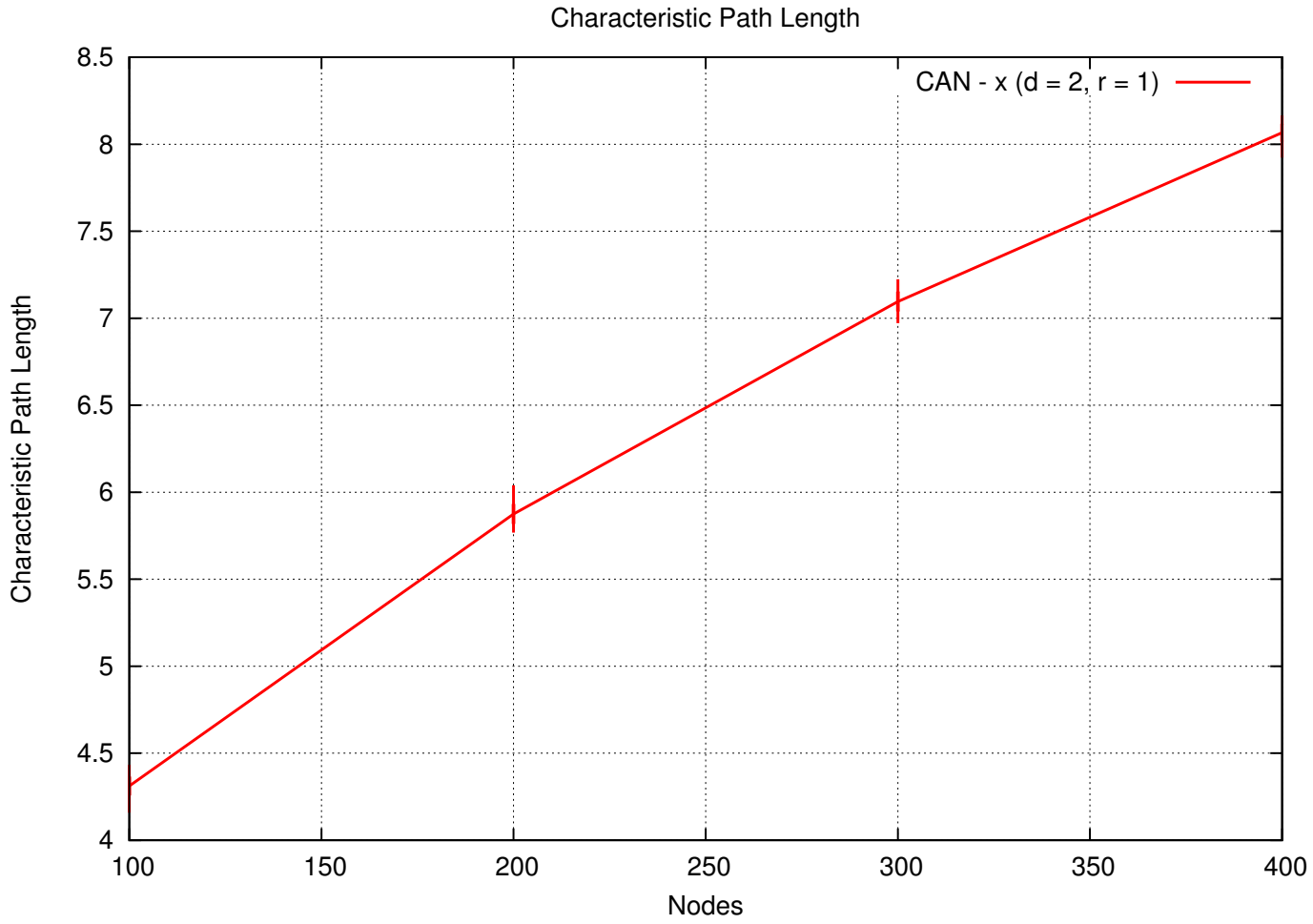
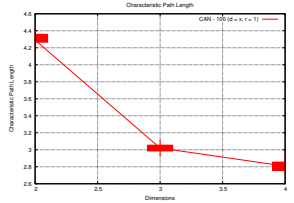
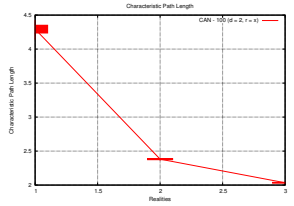
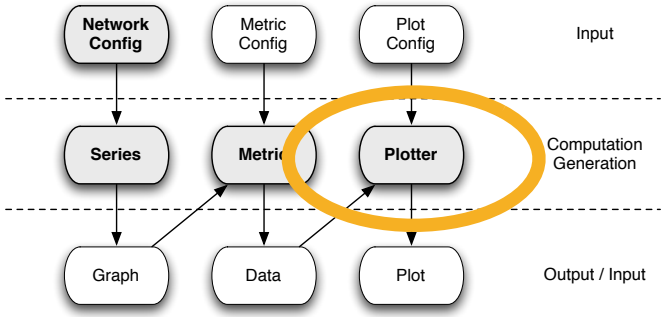


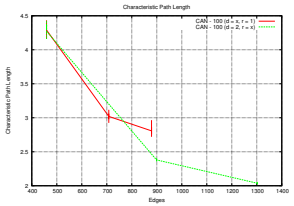




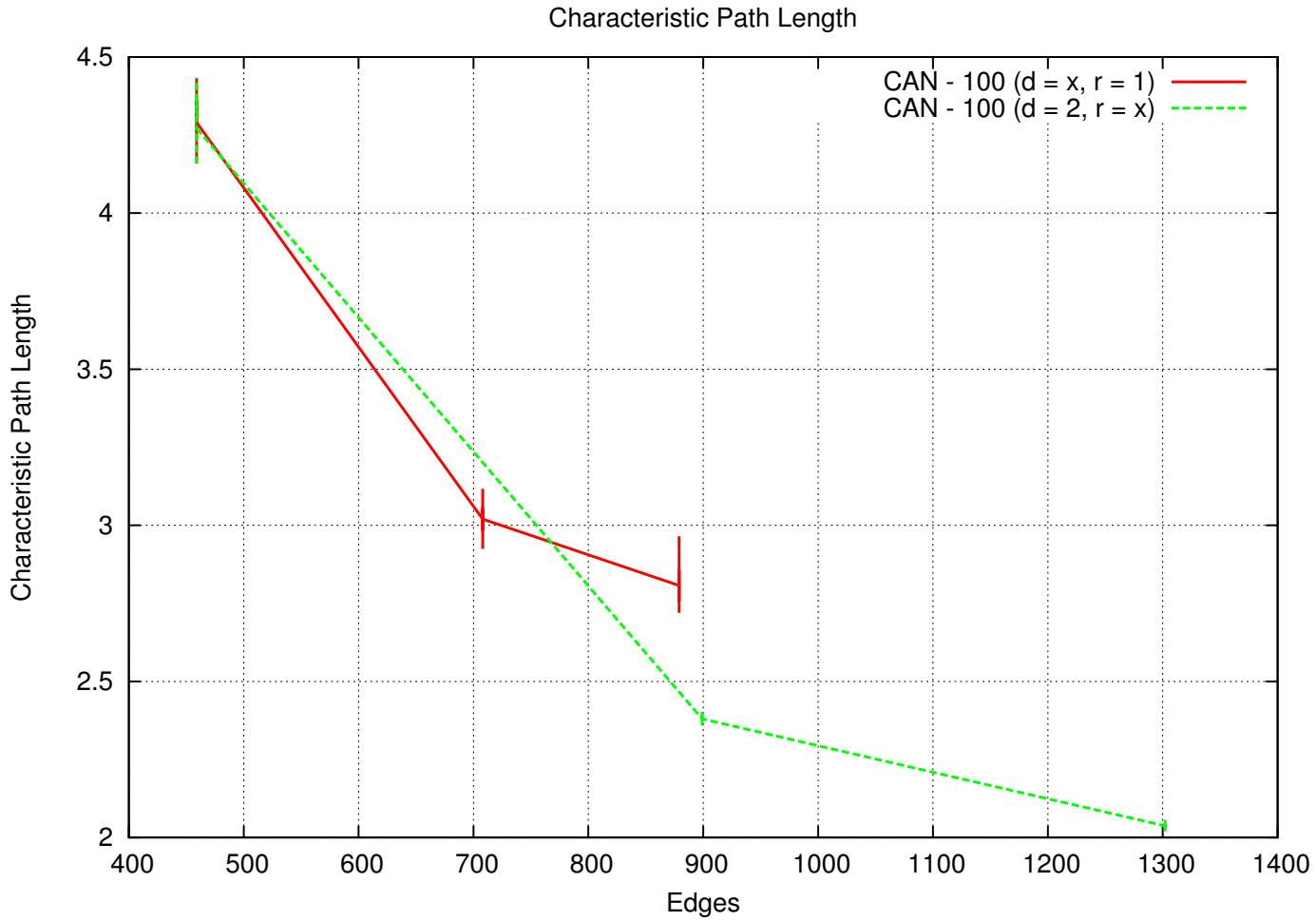
Plotting the Results

```
Series[] s_can_x_1 = Series.get(can_x_1);
Series[] s_can_2_x = Series.get(can_2_x);
Series[] s_can_x = Series.get(can_x);

Plot.allMulti(s_can_x_1, "./can-dimensions/");
Plot.allMulti(s_can_2_x, "./can-realities/");

Plot.allSingle(s_can_x_1, "./can-dimensions-singles/");
Plot.allSingle(s_can_2_x, "./can-realities-singles/");
Plot.allSingle(s_can_x, "./can-nodes-singles/");

Series[][] s_all = new Series[][]{
  s_can_x_1, s_can_2_x };

Plot.allSingleByEdges(s_all, "./can-by-edges/");
```



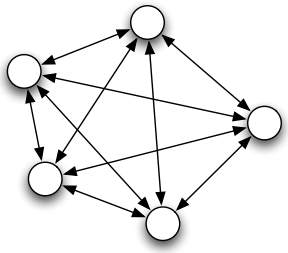


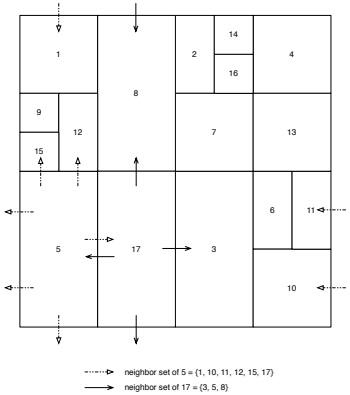
Plotting the Results

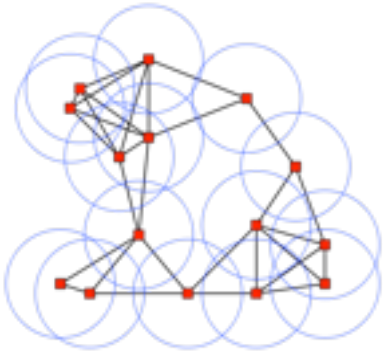


3. Available Networks

Networks already implemented in GTNA

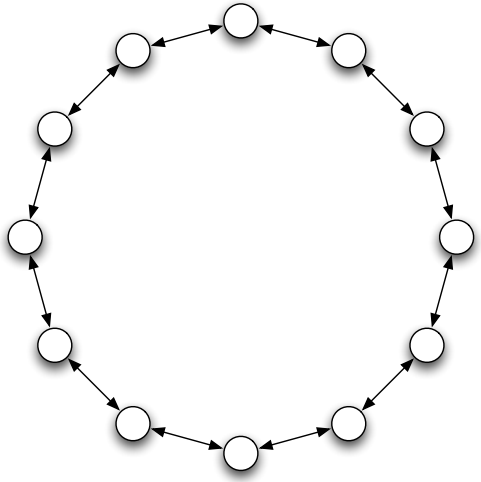


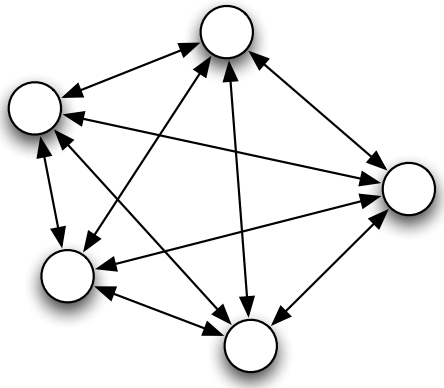


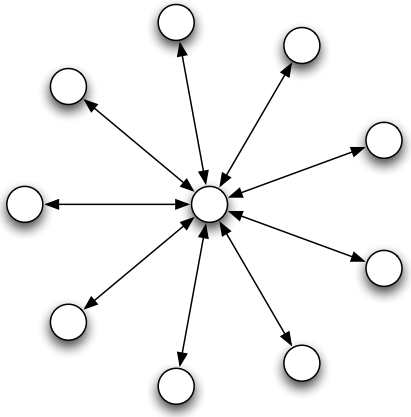


Canonical Networks

- Complete
- Ring
- Star







Network Models

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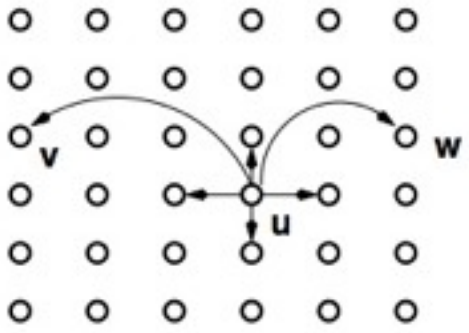
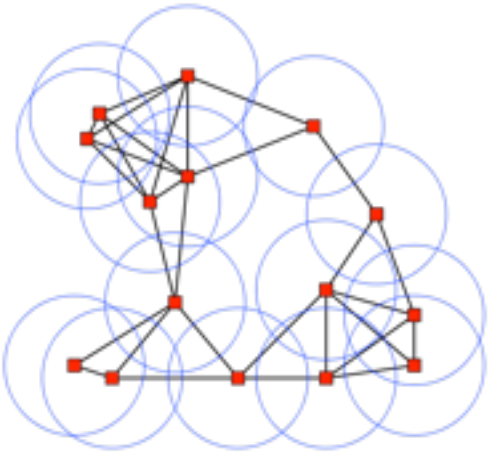
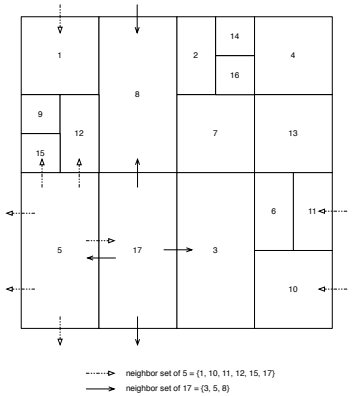
- Barabasi Albert
- De Bruijn
- Erdos Renyi
- Gilbert
- GNC - Growing Network with Copying
- GNR - Growing Network with Re-direction
- Kleinberg
- UnitDisc
- Watts Strogatz

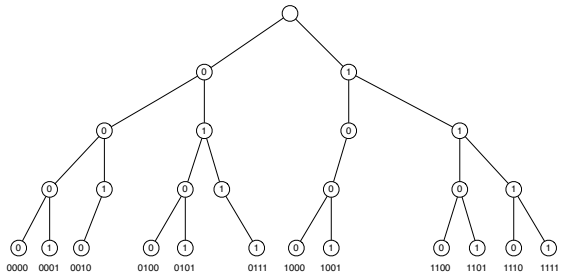




Peer-to-Peer Networks

- CAN
- Chord
- Gnutella 0.4
- Gnutella 0.6
- Kademlia
- ODRI - Optimal Diameter Routing Infrastructure
- Pastry
- PathFinder
- Symphony



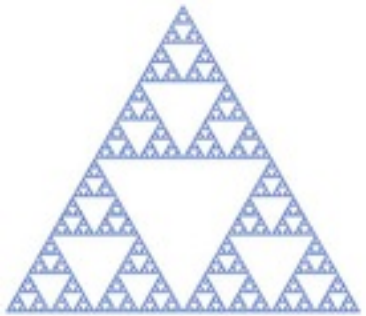


Misc Networks

- Utilities
  - Readable File
  - Readable List

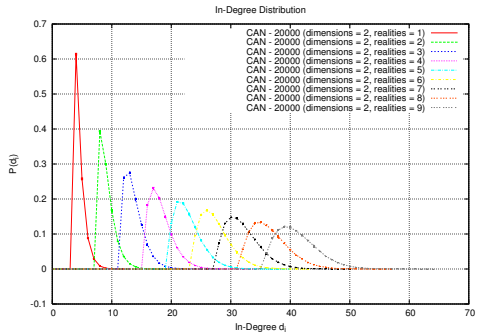
1. own format
2. edges only
3. GML
4. caida.org Internet traces

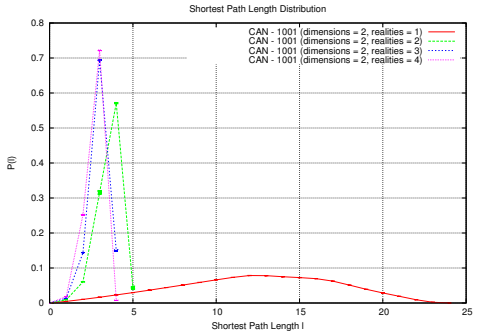
- Transformations
  - Add Edges Per Node
  - Add Edges Randomly
  - Rewire
  - Same Degree Distribution

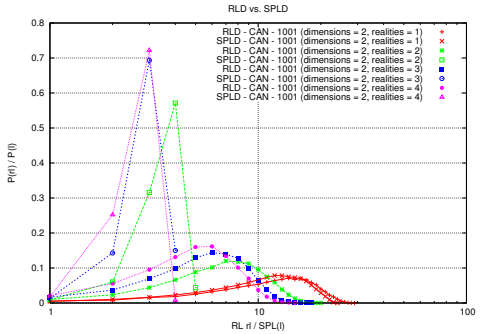


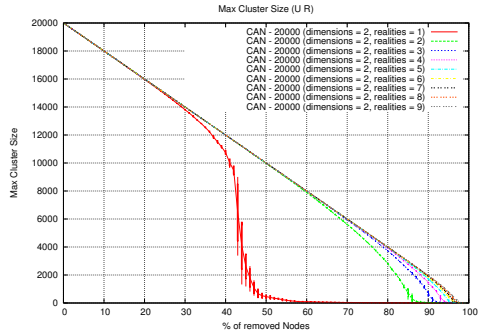
4. Available Metrics

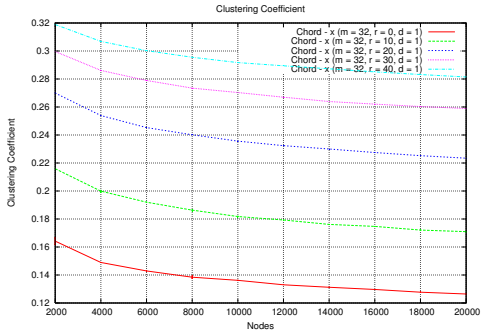
Metrics already implemented in GTNA

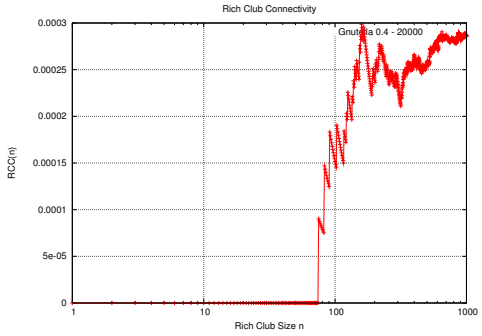








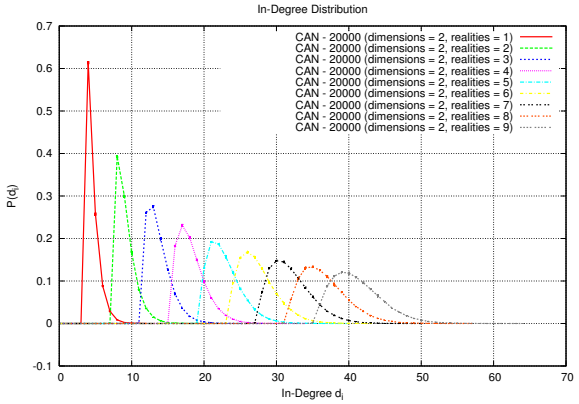


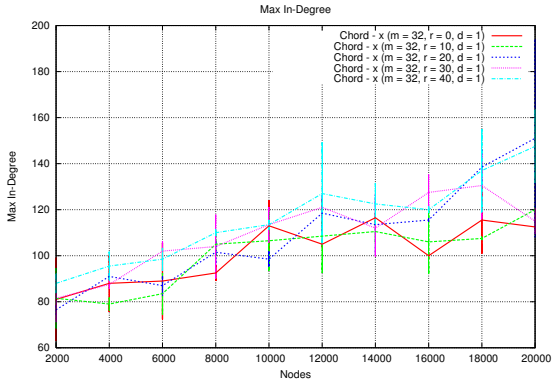


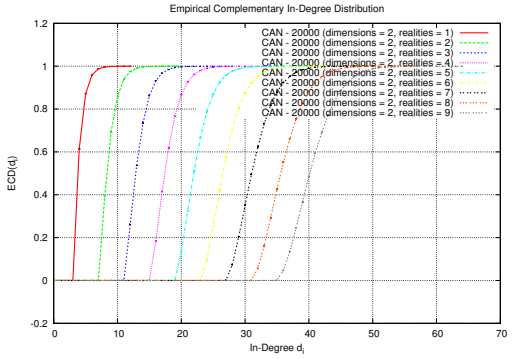
Degree Distribution

- (in-/out-)Degree Distribution
- Empirical Complementary (in-/out-)Degree Distribution

- #Nodes, #Edges
- Average Degree
- Min (in-/out-)Degree
- Max (in-/out-)Degree



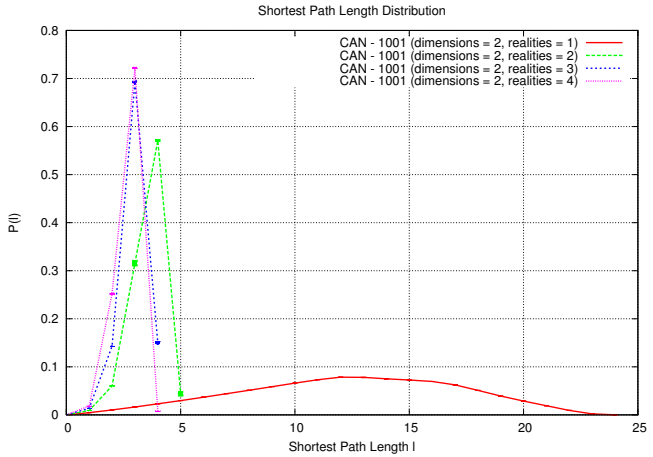


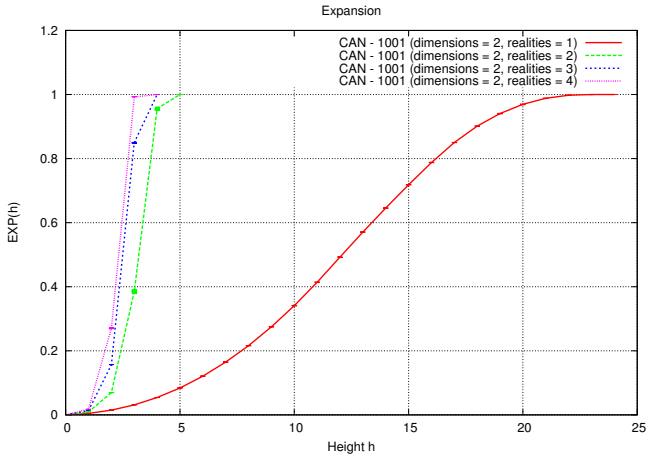


Shortest Path Length

- Shortest Path Length Distribution
- Expansion
- Local Characteristic Path Length

- Characteristic Path Length
- Diameter

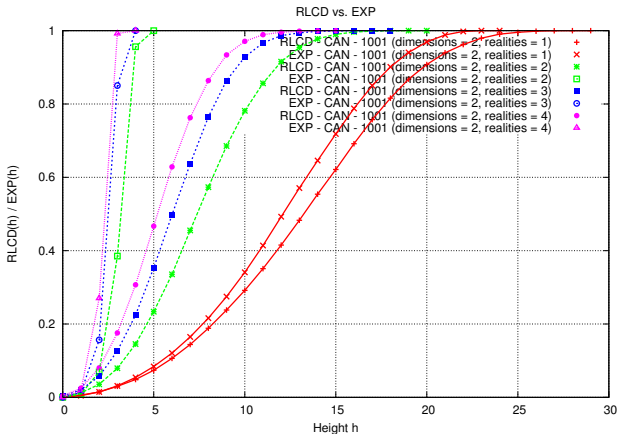


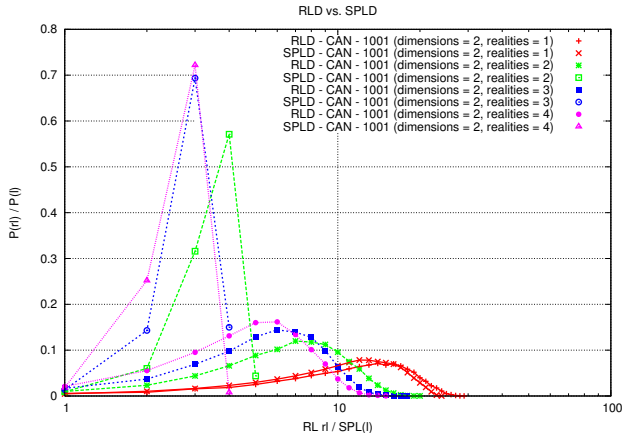


Routing Length

- Routing Length Distribution
- Routing Length Complementary Distribution
- Local Characteristic Routing Length

- Characteristic Routing Length
- Max Routing Length

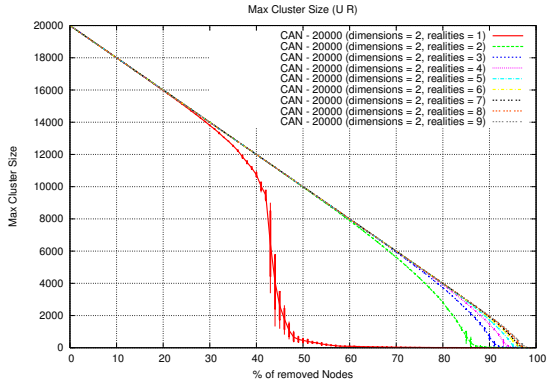


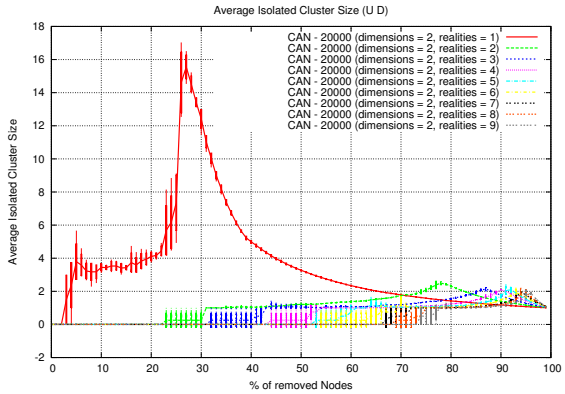


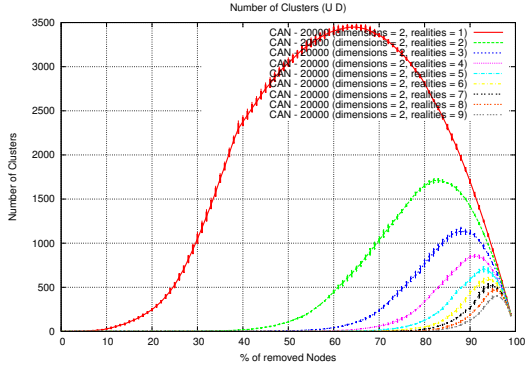
Network Fragmentation

- Max Cluster Size
- Number of Clusters
- Average Isolated Cluster Size

- Point of Rupture
- Average Number of Clusters
- Max Number of Clusters

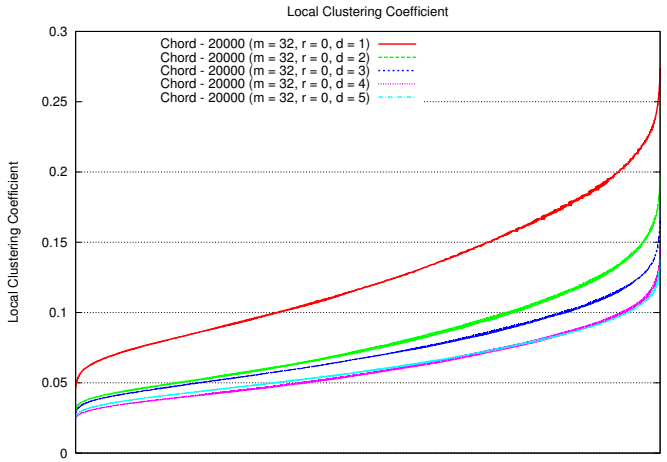


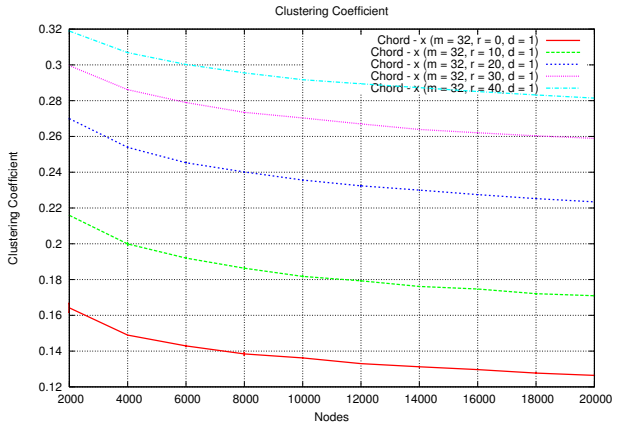




Clustering Coefficient

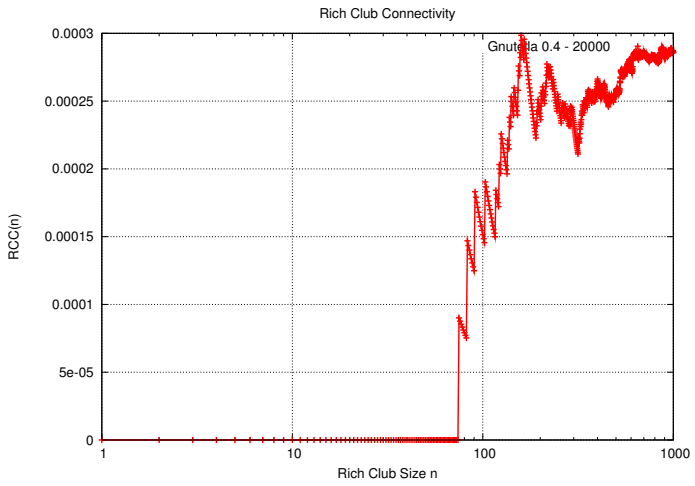
- Local Clustering Coefficient
- Clustering Coefficient
- Weighted Clustering Coefficient

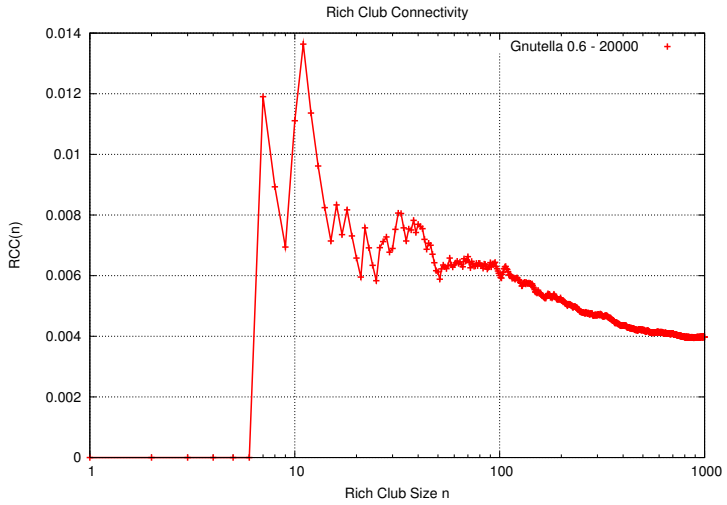




Rich Club Connectivity

- Rich Club Connectivity





5. Extension

Implementation and Configuration of new Networks / Metrics

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```
public class MyNetwork extends NetworkImpl implements Network {
    private boolean p1;
    public MyNetwork(int nodes, boolean p1) {
        super("MY_NETWORK", nodes, new String[]{"P1"}, new String[]{"" + p1});
        this.p1 = p1;
    }
    public Graph generate(){
        Timer timer = new Timer();
        Node[] nodes = Node.init(this.nodes());
        Edges edges = new Edges(nodes, 100);
        for(int i=1; i<nodes.length; i++){
            edges.add(nodes[0], nodes[i]);
            if(this.p1)
                edges.add(nodes[i], nodes[0]);
        }
        edges.fill();
        return new Graph(this.description(), nodes, timer);
    }
}
```

+

```
NOD_CLASS = gtna.metrics.NodesOfDegree
NOD_NAME = Nodes of Degree
NOD_DATA_KEYS = NOD_NOD
NOD_SINGLES_KEYS = NOD_DOMN
NOD_DATA_PLOTS = NOD
NOD_SINGLES_PLOTS = DOMN

NOD_NOD_DATA_NAME = Nodes of Degree
NOD_NOD_DATA_FILENAME = nod

NOD_DOMN_SINGLE_NAME = Degree of Most Nodes

NOD_PLOT_DATA = NOD_NOD
NOD_PLOT_FILENAME = nod
NOD_PLOT_TITLE = Nodes of Degree
NOD_PLOT_X = degree d
NOD_PLOT_Y = # nodes of degree d

DOMN_PLOT_DATA = NOD_DOMN
DOMN_PLOT_FILENAME = domn
DOMN_PLOT_TITLE = Degree of Most Nodes
DOMN_PLOT_Y = Degree of Most Nodes
```

Implementing a new Network

TECHNISCHE UNIVERSITÄT DARMSTADT

```
public class MyNetwork extends NetworkImpl implements Network {
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        edges.add(nodes[0], nodes[i]);
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  }
}
```

Implementing a new Network

TECHNISCHE UNIVERSITÄT DARMSTADT

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        edges.add(nodes[0], nodes[i]);
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    edges.fill();
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  }
}
```

Implementing a new Network

TECHNISCHE UNIVERSITÄT DARMSTADT

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      if(this.p1)
        edges.add(nodes[0], nodes[i]);
    }
    edges.fill();
    return new Graph(this.description(), nodes, timer);
  }
}
```

Parameter

Implementing a new Network

TECHNISCHE UNIVERSITÄT DARMSTADT

```
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    Edges edges = new Edges(nodes, 100);
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        edges.add(nodes[0], nodes[i]);
    }
    edges.fill();
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  }
}
```

Parameter

Constructor

Implementing a new Network

TECHNISCHE UNIVERSITÄT DARMSTADT

```
public class MyNetwork extends NetworkImpl implements Network {
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    Edges edges = new Edges(nodes, 100);
    for(int i=1; i<nodes.length; i++){
      edges.add(nodes[i], nodes[0]);
      if(this.p1)
        edges.add(nodes[0], nodes[i]);
    }
    edges.fill();
    return new Graph(this.description(), nodes, timer);
  }
}
```

Parameter

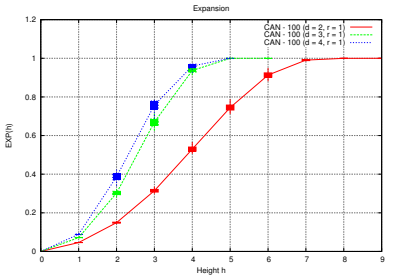
Constructor

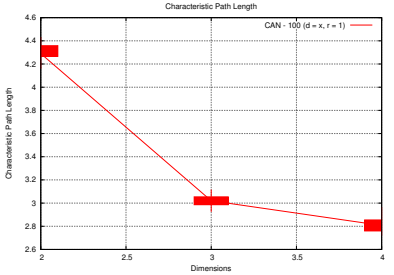
Generator

Fachbereich Informatik

Configuring a new Network

```
CAN_NETWORK_NAME = CAN

CAN_NETWORK_FOLDER = can

CAN_NETWORK_DIMENSIONS_NAME = Dimensions
CAN_NETWORK_DIMENSIONS_NAME_LONG = dimensions
CAN_NETWORK_DIMENSIONS_NAME_SHORT = d

CAN_NETWORK_REALITIES_NAME = Realities
CAN_NETWORK_REALITIES_NAME_LONG = realities
CAN_NETWORK_REALITIES_NAME_SHORT = r
```

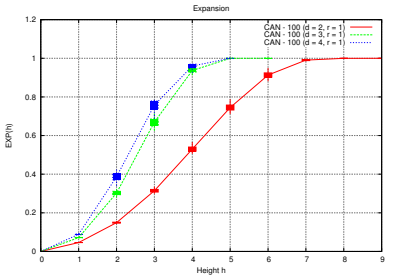


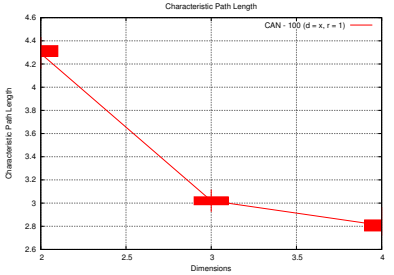


Configuring a new Network

TECHNISCHE UNIVERSITÄT DARMSTADT

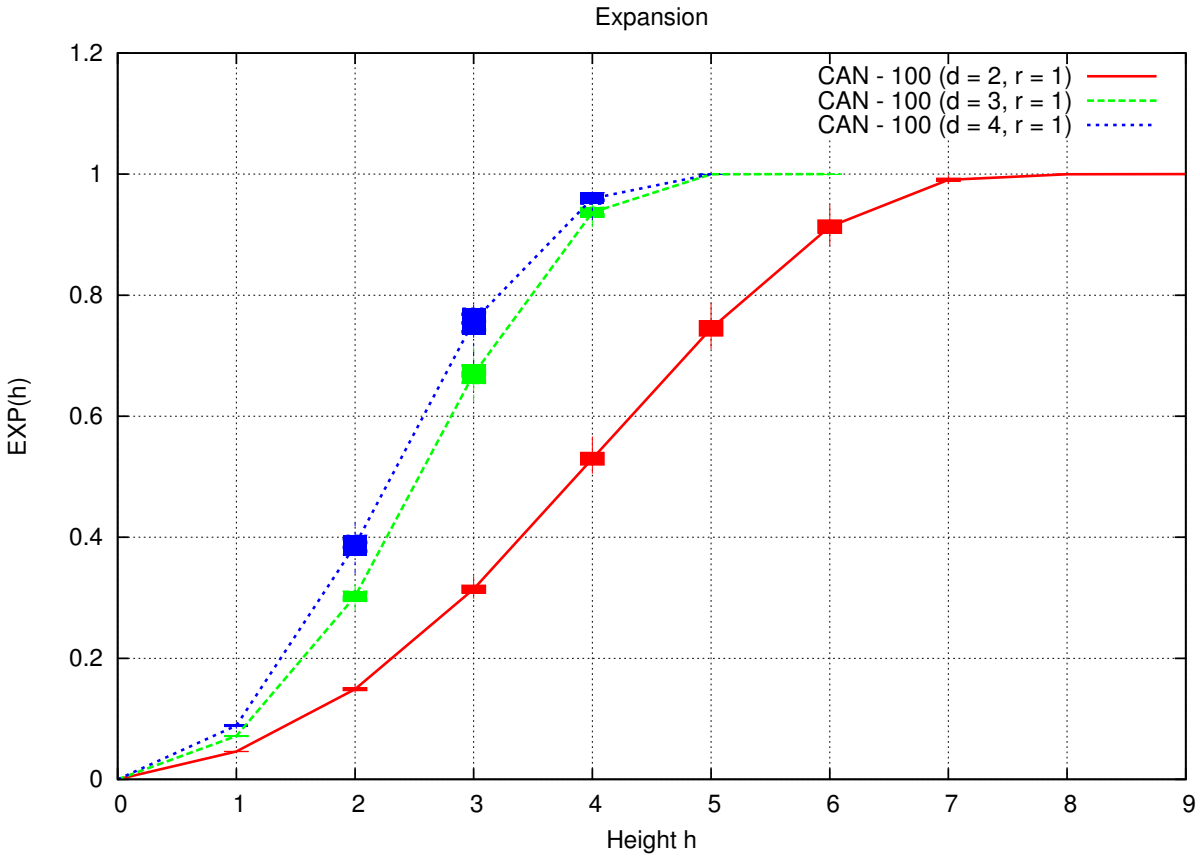
```
CAN_NETWORK_NAME = CAN

CAN_NETWORK_FOLDER = can

CAN_NETWORK_DIMENSIONS_NAME = Dimensions
CAN_NETWORK_DIMENSIONS_NAME_LONG = dimensions
CAN_NETWORK_DIMENSIONS_NAME_SHORT = d

CAN_NETWORK_REALITIES_NAME = Realities
CAN_NETWORK_REALITIES_NAME_LONG = realities
CAN_NETWORK_REALITIES_NAME_SHORT = r
```

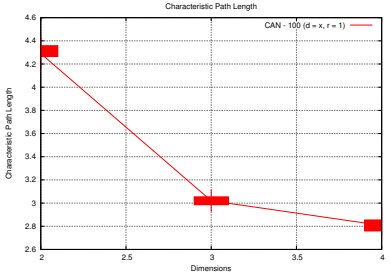




Informatik Fachbereich Informatik

Configuring a new Network

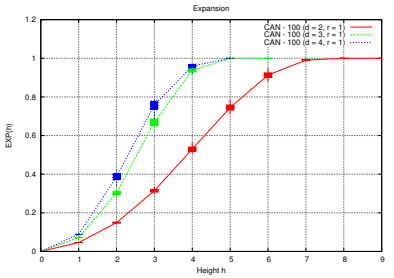


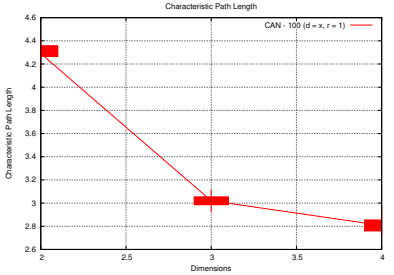


Configuring a new Network

TECHNISCHE UNIVERSITÄT DARMSTADT

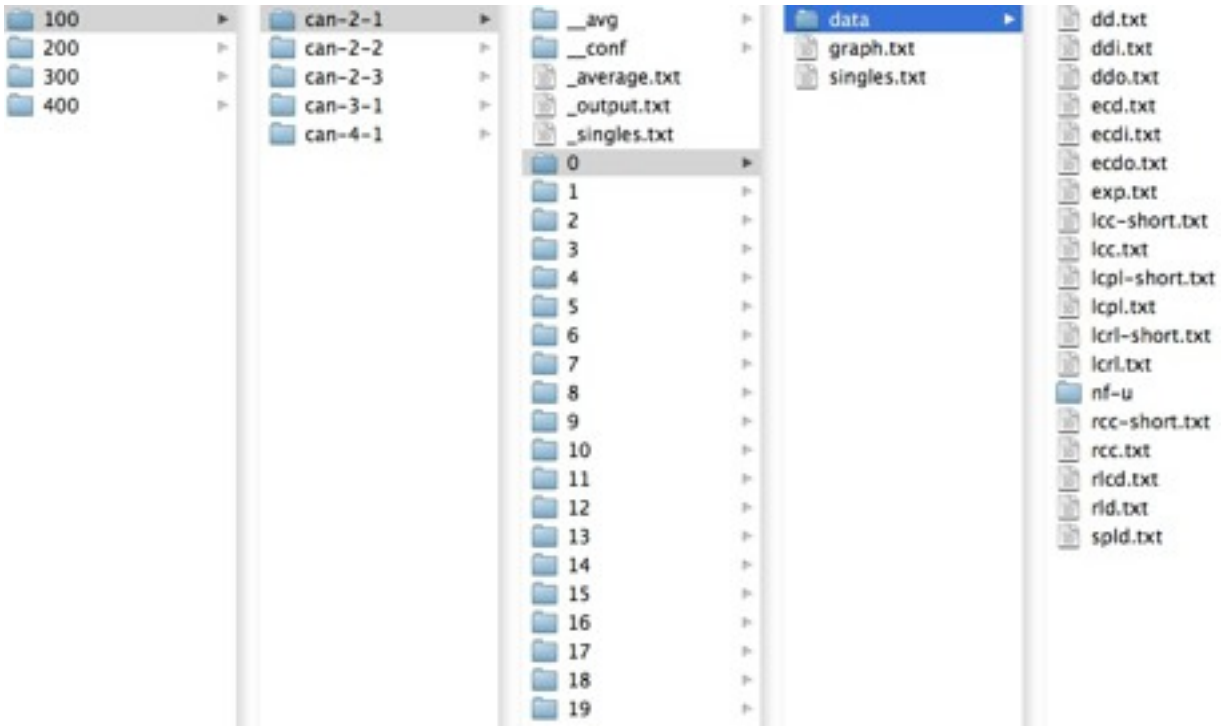
```
CAN_NETWORK_NAME = CAN

CAN_NETWORK_FOLDER = can

CAN_NETWORK_DIMENSIONS_NAME = Dimensions
CAN_NETWORK_DIMENSIONS_NAME_LONG = dimensions
CAN_NETWORK_DIMENSIONS_NAME_SHORT = d

CAN_NETWORK_REALITIES_NAME = Realities
CAN_NETWORK_REALITIES_NAME_LONG = realities
CAN_NETWORK_REALITIES_NAME_SHORT = r
```

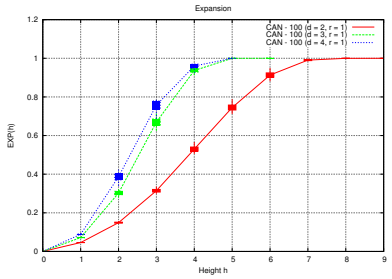


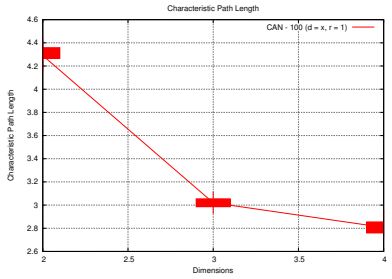


Informatik Fachbereich Informatik

Configuring a new Network



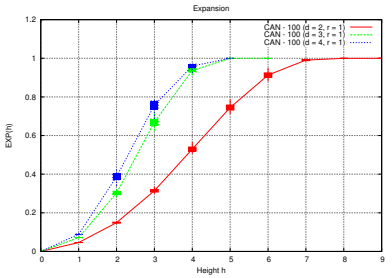


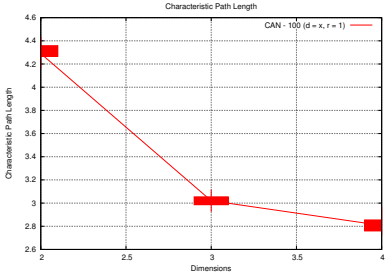


Configuring a new Network

TECHNISCHE UNIVERSITÄT DARMSTADT

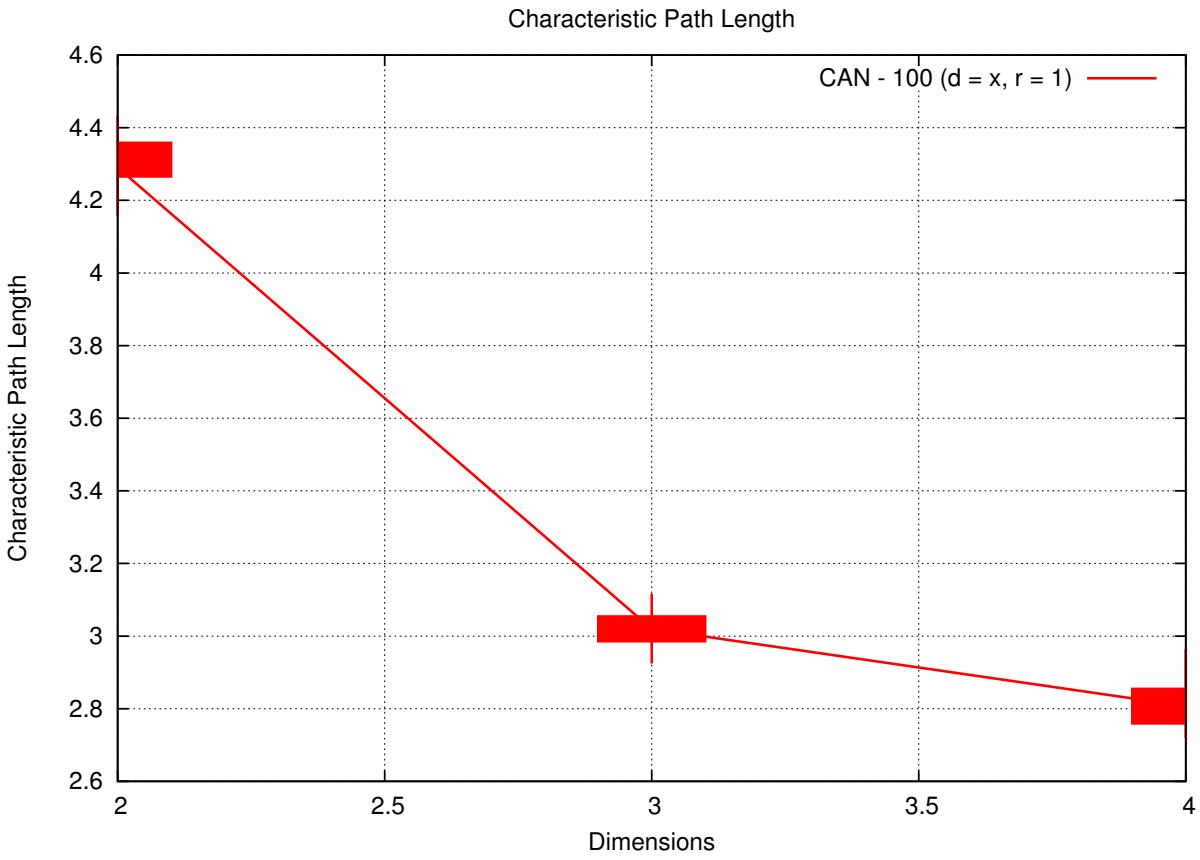
```
CAN_NETWORK_NAME = CAN

CAN_NETWORK_FOLDER = can

CAN_NETWORK_DIMENSIONS_NAME = Dimensions
CAN_NETWORK_DIMENSIONS_NAME_LONG = dimensions
CAN_NETWORK_DIMENSIONS_NAME_SHORT = d

CAN_NETWORK_REALITIES_NAME = Realities
CAN_NETWORK_REALITIES_NAME_LONG = realities
CAN_NETWORK_REALITIES_NAME_SHORT = r
```

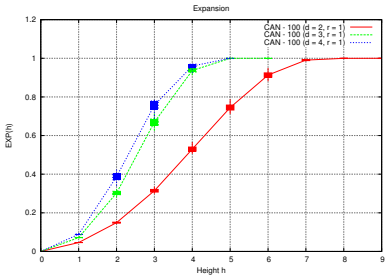




Informatik Fachbereich Informatik

Configuring a new Network





Implementing a new Metric

TECHNISCHE UNIVERSITÄT DARMSTADT

```
public class MyMetric extends MetricImpl implements Metric {
  private int[] nod;
  private int domn;
  public MyMetric() { super("NOD"); }
  public void computeData(Graph g) {
    this.nod = new int[g.maxDegree + 1];
    for (int i = 0; i < g.nodes.length; i++)
      this.nod[g.nodes[i].degree]++;
    this.domn = Util.maxIndex(this.nod);
  }
  public Value[] getValues(Value[] values) {
    return new Value[] { new Value("NOD_DOMN", this.domn) };
  }
  public boolean writeData(String folder) {
    DataWriter.write("NOD_NOD", folder, this.nod);
    return true;
  }
}
```

Implementing a new Metric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Attributes

Implementing a new Metric

TECHNISCHE UNIVERSITÄT DARMSTADT

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  }
  public Value[] getValues(Value[] values) {
    return new Value[] { new Value("NOD_DOMN", this.domn) };
  }
  public boolean writeData(String folder) {
    DataWriter.write("NOD_NOD", folder, this.nod);
    return true;
  }
}
```

Attributes

Constructor

Implementing a new Metric

TECHNISCHE UNIVERSITÄT DARMSTADT

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  }
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    return new Value[] { new Value("NOD_DOMN", this.domn) };
  }
  public boolean writeData(String folder) {
    DataWriter.write("NOD_NOD", folder, this.nod);
    return true;
  }
}
```

Attributes

Constructor

Computation

Implementing a new Metric

TECHNISCHE UNIVERSITÄT DARMSTADT

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  }
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    return new Value[] { new Value("NOD_DOMN", this.domn) };
  }
  public boolean writeData(String folder) {
    DataWriter.write("NOD_NOD", folder, this.nod);
    return true;
  }
}
```

Attributes

Constructor

Computation

Output

Configuring a new Metric

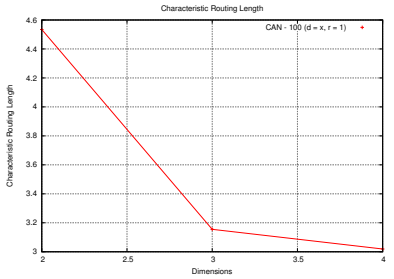
```
RL_CLASS = gtna.metrics.RoutingLength
RL_NAME = Routing Length
RL_SINGLES_KEYS = CRL
RL_DATA_KEYS = RLD
RL_SINGLES_PLOTS = CRL
RL_DATA_PLOTS = RLD

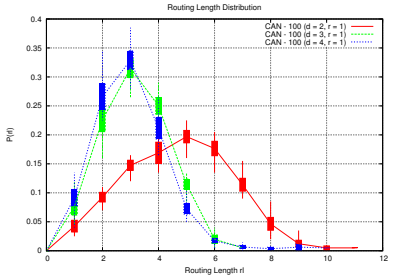
CRL_SINGLE_NAME = Characteristic Routing Length

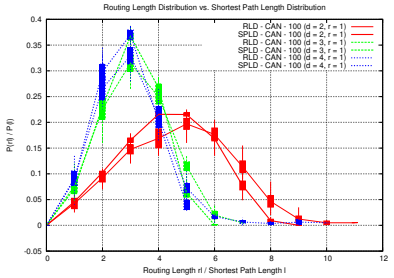
RLD_DATA_NAME = Routing Length Distribution
RLD_DATA_FILENAME = RLD

CRL_PLOT_DATA = CRL
CRL_PLOT_FILENAME = crl
CRL_PLOT_TITLE = Characteristic Routing Length
CRL_PLOT_Y = CRL

RLD_PLOT_DATA = RLD
RLD_PLOT_FILENAME = rld
RLD_PLOT_TITLE = Routing Length Distribution
RLD_PLOT_X = Routing Length rl
RLD_PLOT_Y = P(rl)
```







Configuring a new Metric

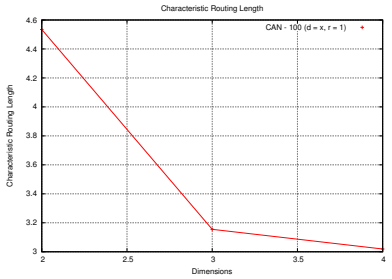
```
RL_CLASS = gtna.metrics.RoutingLength
RL_NAME = Routing Length
RL_SINGLES_KEYS = CRL
RL_DATA_KEYS = RLD
RL_SINGLES_PLOTS = CRL
RL_DATA_PLOTS = RLD

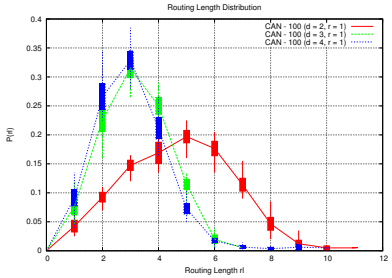
CRL_SINGLE_NAME = Characteristic Routing Length

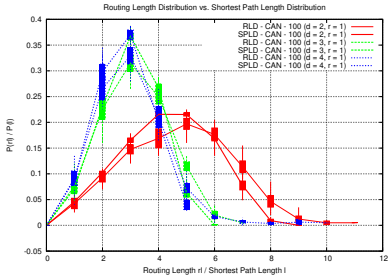
RLD_DATA_NAME = Routing Length Distribution
RLD_DATA_FILENAME = RLD

CRL_PLOT_DATA = CRL
CRL_PLOT_FILENAME = crl
CRL_PLOT_TITLE = Characteristic Routing Length
CRL_PLOT_Y = CRL

RLD_PLOT_DATA = RLD
RLD_PLOT_FILENAME = rld
RLD_PLOT_TITLE = Routing Length Distribution
RLD_PLOT_X = Routing Length rl
RLD_PLOT_Y = P(rl)
```







Configuring a new Metric

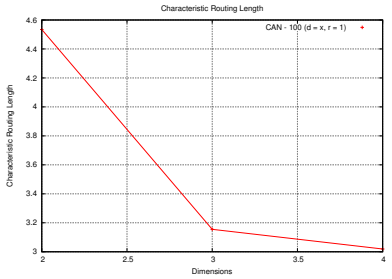
```
RL_CLASS = gtna.metrics.RoutingLength
RL_NAME = Routing Length
RL_SINGLES_KEYS = CRL
RL_DATA_KEYS = RLD
RL_SINGLES_PLOTS = CRL
RL_DATA_PLOTS = RLD

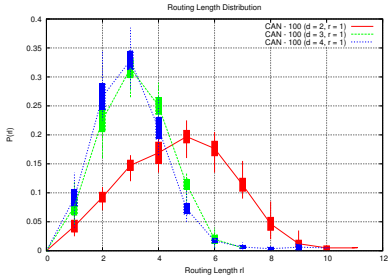
CRL_SINGLE_NAME = Characteristic Routing Length

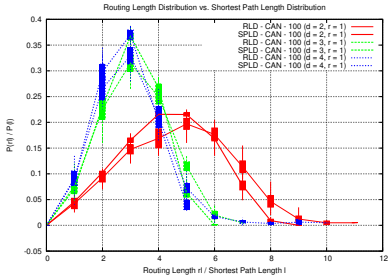
RLD_DATA_NAME = Routing Length Distribution
RLD_DATA_FILENAME = RLD

CRL_PLOT_DATA = CRL
CRL_PLOT_FILENAME = crl
CRL_PLOT_TITLE = Characteristic Routing Length
CRL_PLOT_Y = CRL

RLD_PLOT_DATA = RLD
RLD_PLOT_FILENAME = rld
RLD_PLOT_TITLE = Routing Length Distribution
RLD_PLOT_X = Routing Length rl
RLD_PLOT_Y = P(rl)
```







Configuring a new Metric

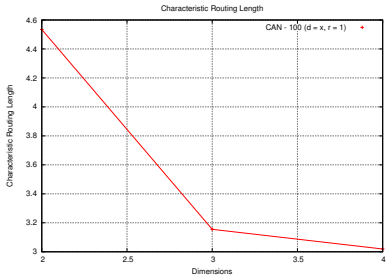
```
RL_CLASS = gtna.metrics.RoutingLength
RL_NAME = Routing Length
RL_SINGLES_KEYS = CRL
RL_DATA_KEYS = RLD
RL_SINGLES_PLOTS = CRL
RL_DATA_PLOTS = RLD

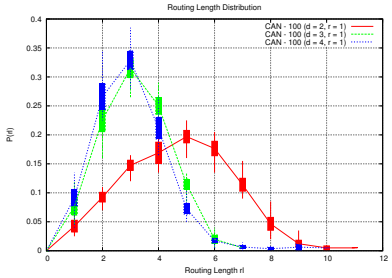
CRL_SINGLE_NAME = Characteristic Routing Length

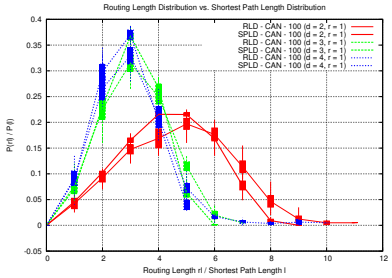
RLD_DATA_NAME = Routing Length Distribution
RLD_DATA_FILENAME = RLD

CRL_PLOT_DATA = CRL
CRL_PLOT_FILENAME = crl
CRL_PLOT_TITLE = Characteristic Routing Length
CRL_PLOT_Y = CRL

RLD_PLOT_DATA = RLD
RLD_PLOT_FILENAME = rld
RLD_PLOT_TITLE = Routing Length Distribution
RLD_PLOT_X = Routing Length rl
RLD_PLOT_Y = P(rl)
```







Configuring a new Metric

```
RL_CLASS = gtna.metrics.RoutingLength
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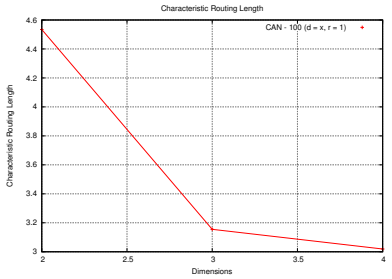
RL_DATA_KEYS = RLD
RL_SINGLES_PLOTS = CRL
RL_DATA_PLOTS = RLD

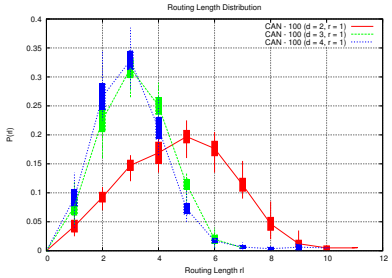
CRL_SINGLE_NAME = Characteristic Routing Length

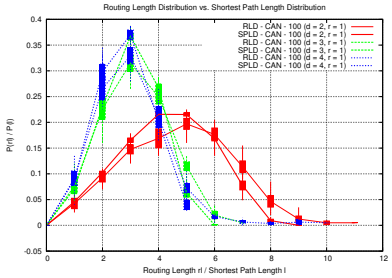
RLD_DATA_NAME = Routing Length Distribution
RLD_DATA_FILENAME = RLD

CRL_PLOT_DATA = CRL
CRL_PLOT_FILENAME = crl
CRL_PLOT_TITLE = Characteristic Routing Length
CRL_PLOT_Y = CRL

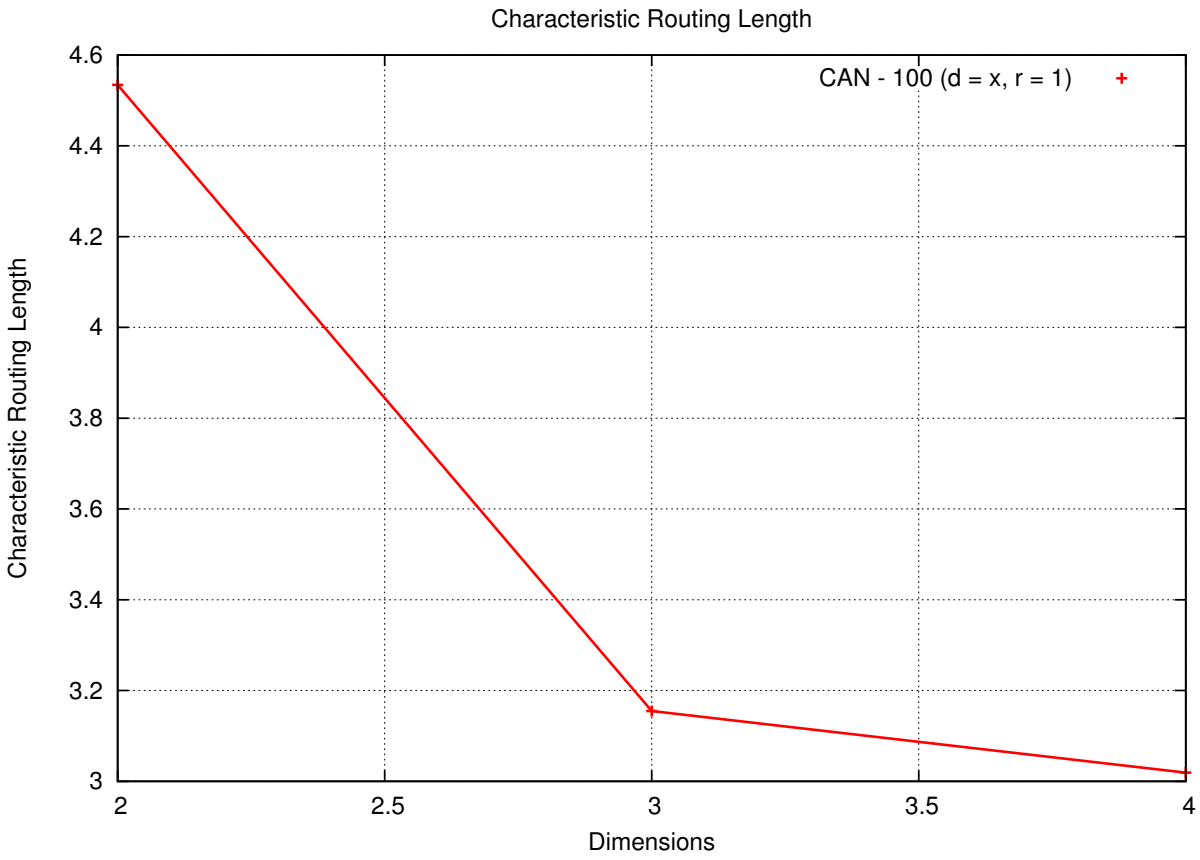
RLD_PLOT_DATA = RLD
RLD_PLOT_FILENAME = rld
RLD_PLOT_TITLE = Routing Length Distribution
RLD_PLOT_X = Routing Length rl
RLD_PLOT_Y = P(rl)
```

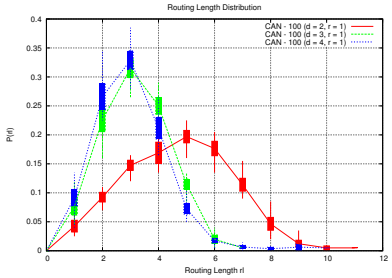


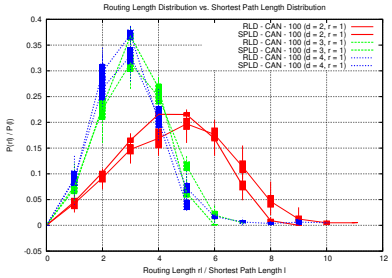




Configuring a new Metric







Configuring a new Metric

```
RL_CLASS = gtna.metrics.RoutingLength
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RL_DATA_KEYS = RLD
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CRL_SINGLE_NAME = Characteristic Routing Length

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RLD_DATA_FILENAME = RLD

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CRL_PLOT_Y = CRL

RLD_PLOT_DATA = RLD
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RLD_PLOT_X = Routing Length rl
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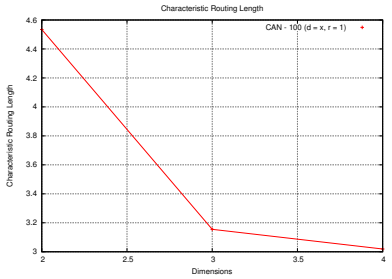
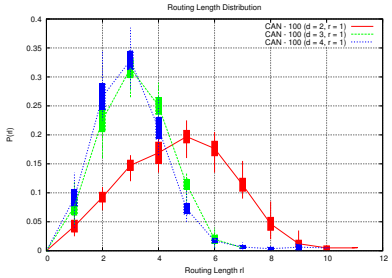
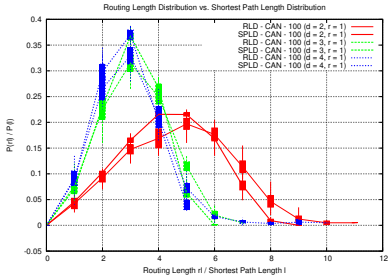
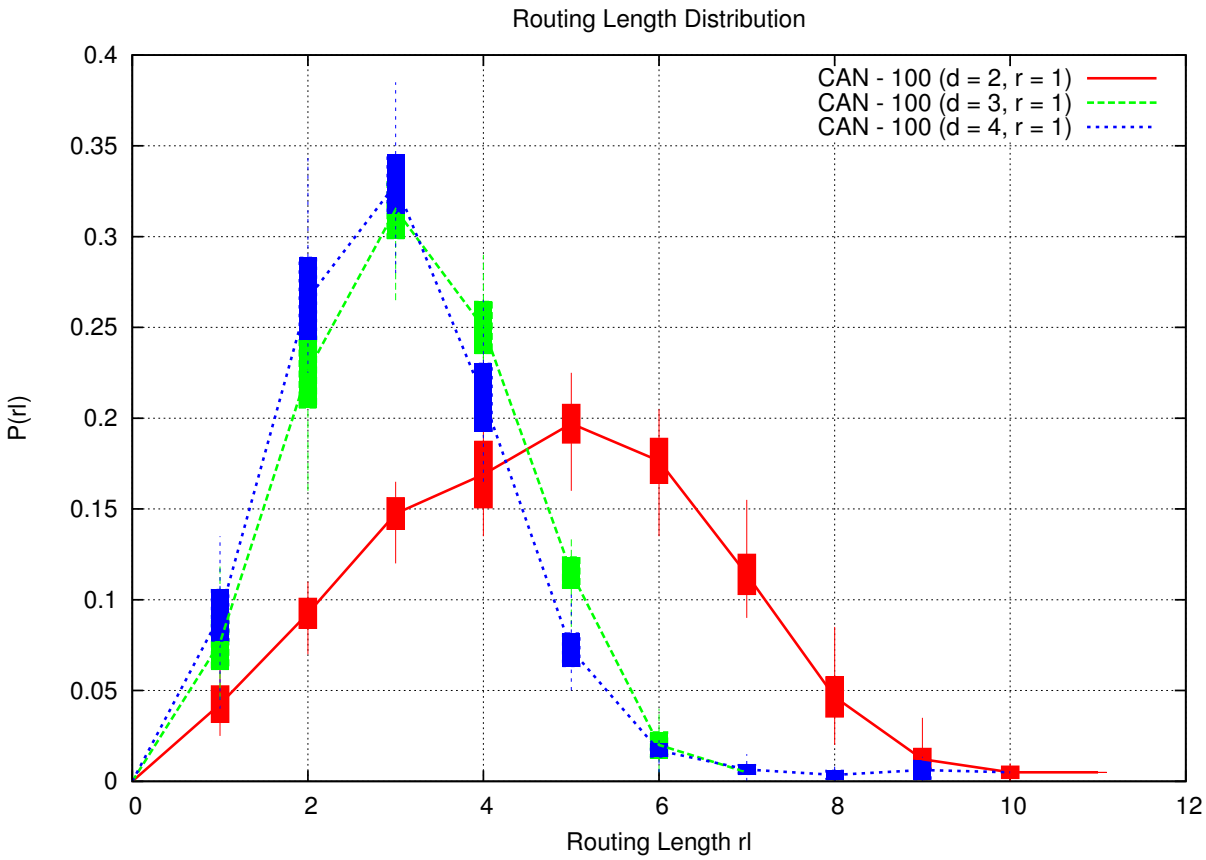
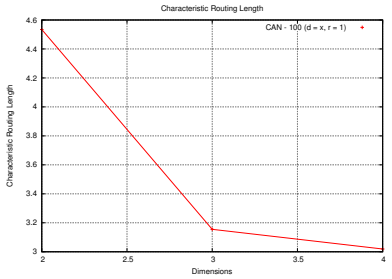


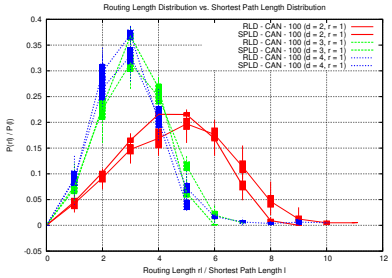




Configuring a new Metric







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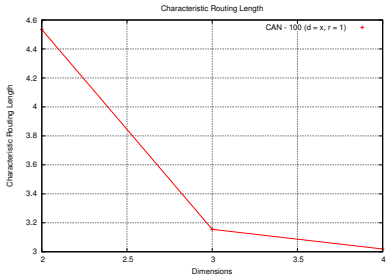
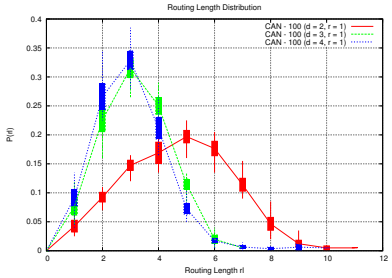
CRL_SINGLE_NAME = Characteristic Routing Length

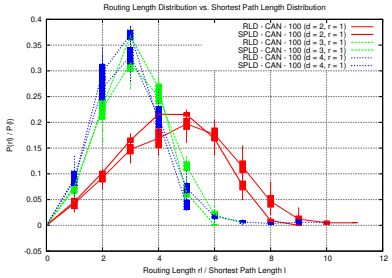
RLD_DATA_NAME = Routing Length Distribution
RLD_DATA_FILENAME = RLD

CRL_PLOT_DATA = CRL
CRL_PLOT_FILENAME = crl
CRL_PLOT_TITLE = Characteristic Routing Length
CRL_PLOT_Y = CRL

RLD_PLOT_DATA = RLD
RLD_PLOT_FILENAME = rld
RLD_PLOT_TITLE = Routing Length Distribution
RLD_PLOT_X = Routing Length rl
RLD_PLOT_Y = P(rl)
```







Configuring a new Metric

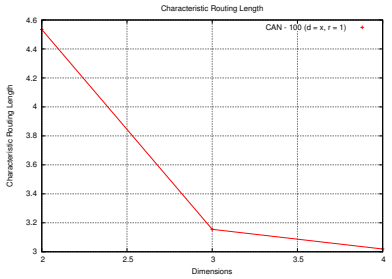
```
RL_CLASS = gtna.metrics.RoutingLength
RL_NAME = Routing Length
RL_SINGLES_KEYS = CRL
RL_DATA_KEYS = RLD
RL_SINGLES_PLOTS = CRL
RL_DATA_PLOTS = RLD

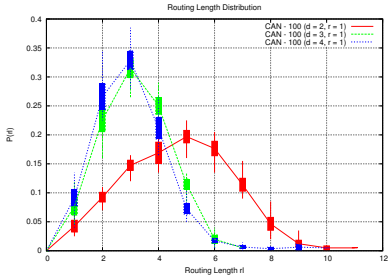
CRL_SINGLE_NAME = Characteristic Routing Length

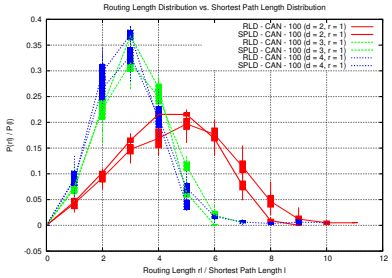
RLD_DATA_NAME = Routing Length Distribution
RLD_DATA_FILENAME = RLD

CRL_PLOT_DATA = CRL
CRL_PLOT_FILENAME = crl
CRL_PLOT_TITLE = Characteristic Routing Length
CRL_PLOT_Y = CRL

RLD_PLOT_DATA = RLD, SPLD
RLD_PLOT_FILENAME = rld-vs-spld
RLD_PLOT_TITLE = RLD vs. SPLD
RLD_PLOT_X = Routing Length rl / Shortest Path Length l
RLD_PLOT_Y = P(rl) / R(l)
```







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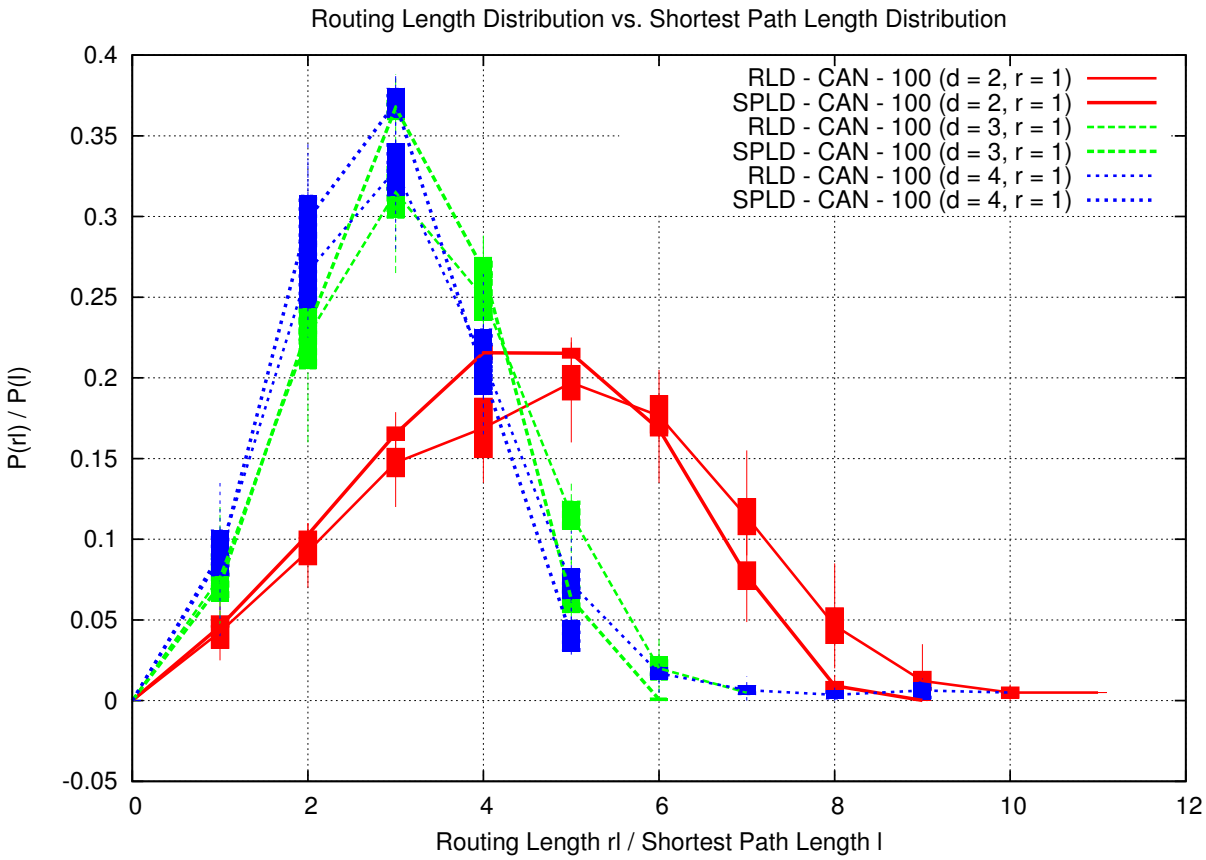

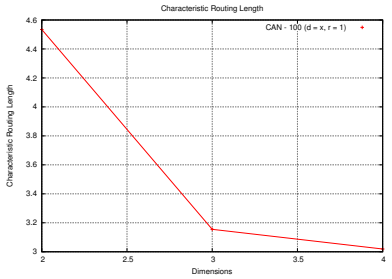

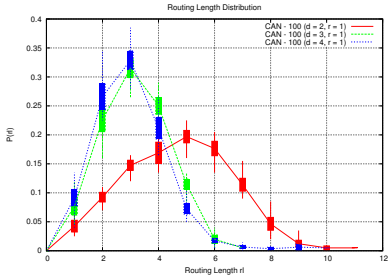

Configuring a new Metric

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```
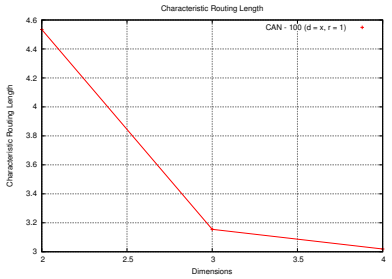
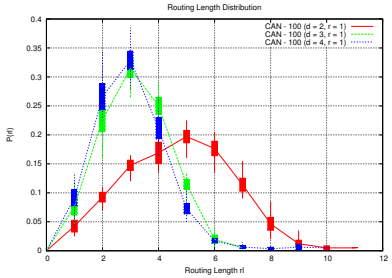
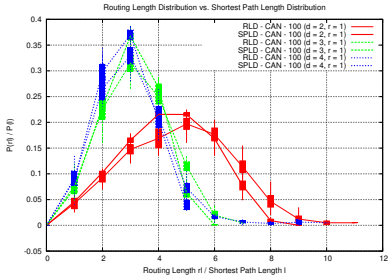
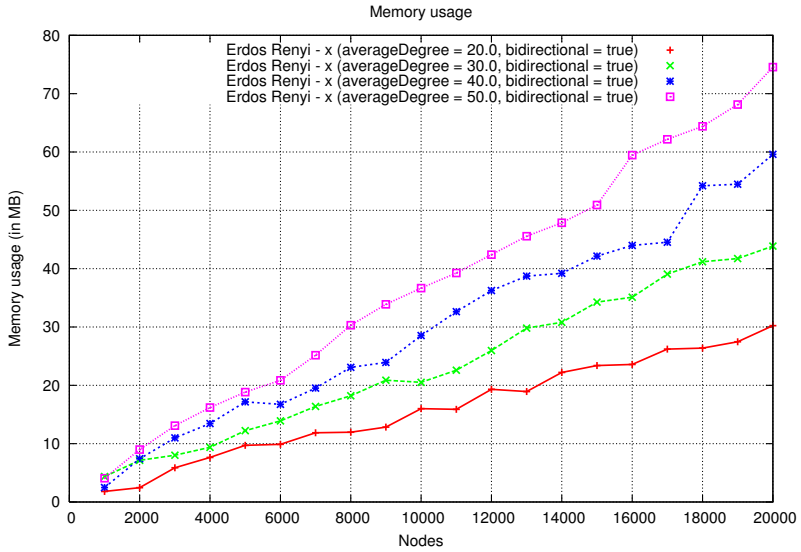



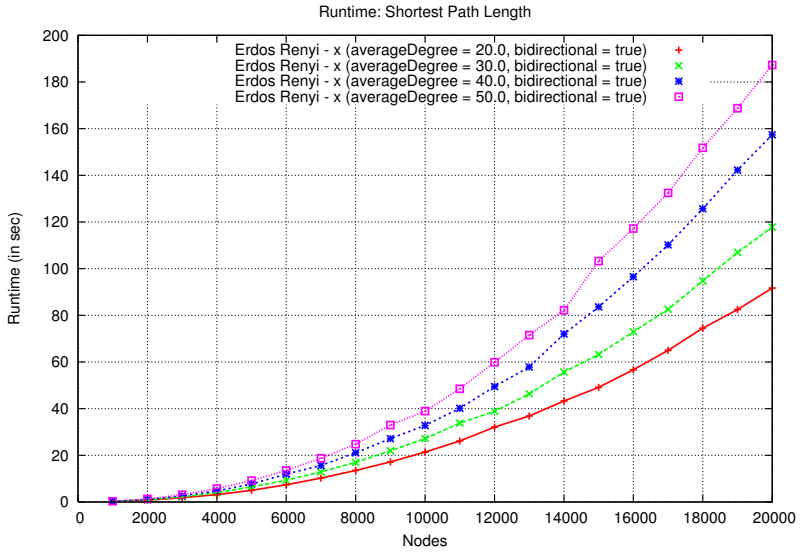




6. Evaluation

Runtime and Memory Usage Evaluation



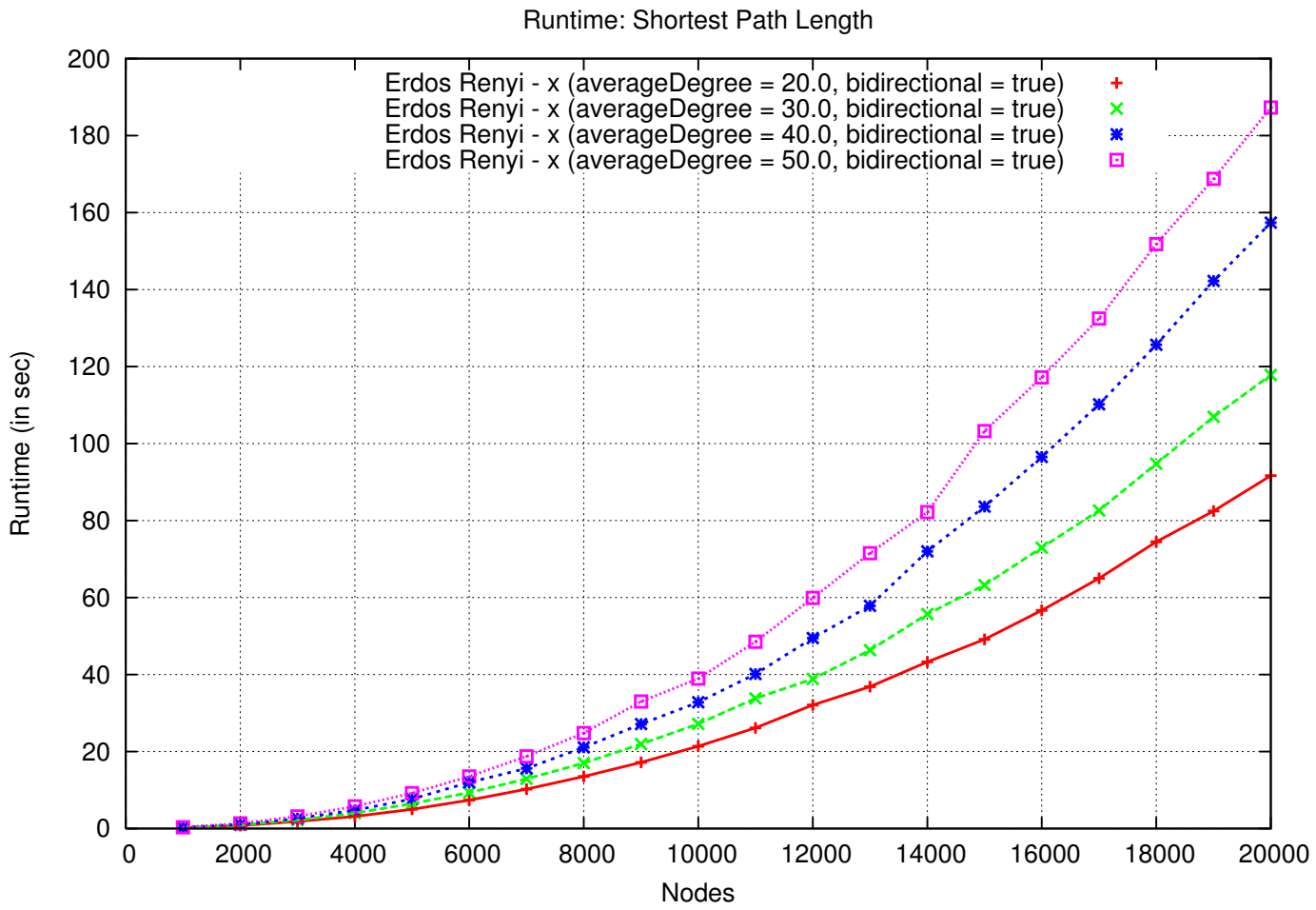


Setup

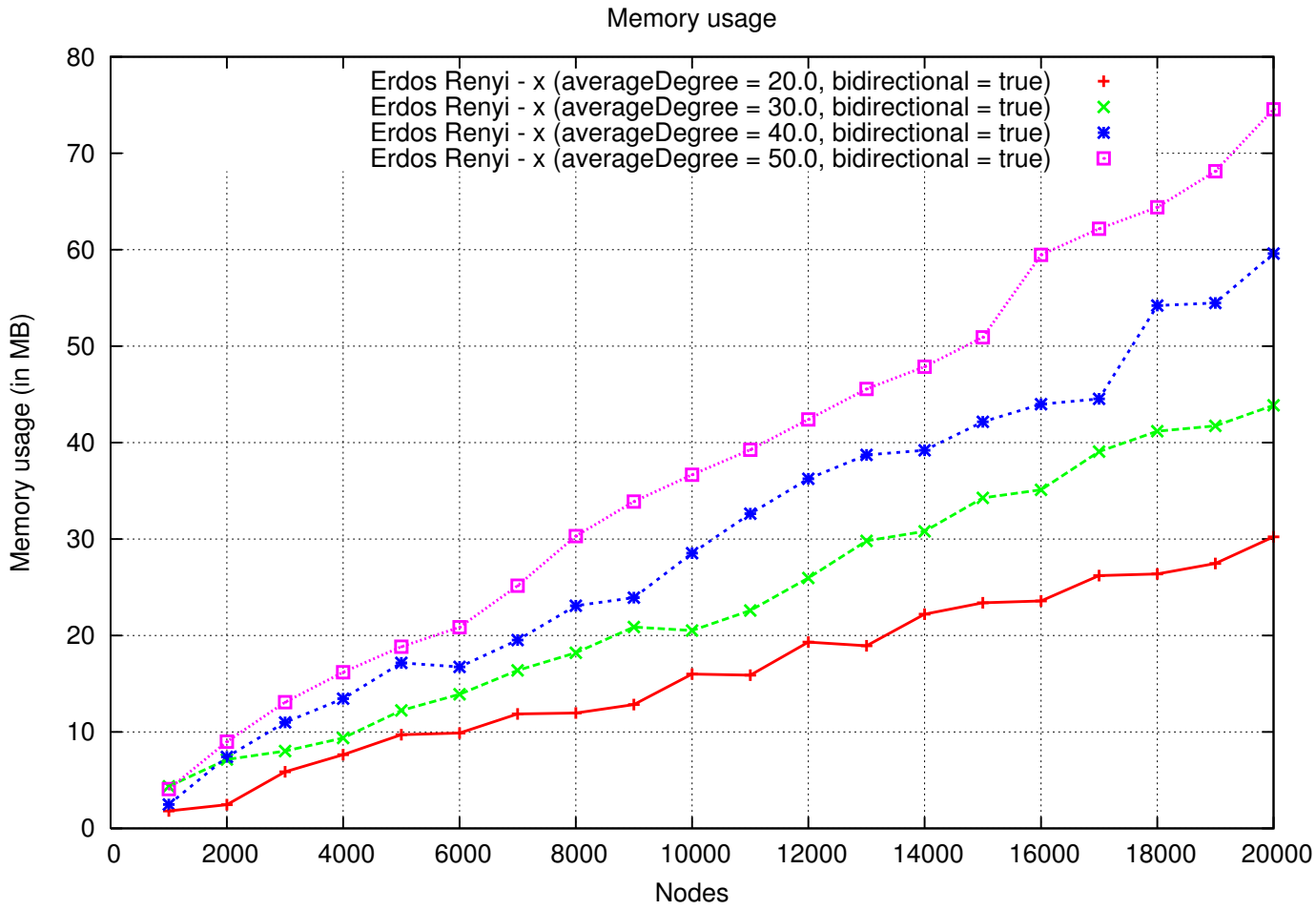
TECHNISCHE UNIVERSITÄT DARMSTADT

- Computer
  - 2.4 GHs Intel Core 2 Duo, 2 GB of Memory
  - MAC OS 10.5.8, Java version 1.5.0_22
- Networks
  - Erdös Rényi random graph
  - $d_{avg} \in \{ 20, 30, 40, 50 \}$
- Runtime: Shortest Path Length
- Memory usage: all metrics

Runtime


Runtime: Shortest Path Length
Erdos Renyi - x (averageDegree = 20.0, bidirectional = true)
Erdos Renyi - x (averageDegree = 30.0, bidirectional = true)
Erdos Renyi - x (averageDegree = 40.0, bidirectional = true)
Erdos Renyi - x (averageDegree = 50.0, bidirectional = true)
Runtime (in sec)
Nodes
0
20
40
60
80
100
120
140
160
180
200
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000

Memory Usage



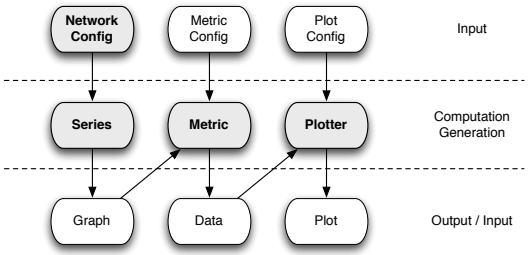
Requirements

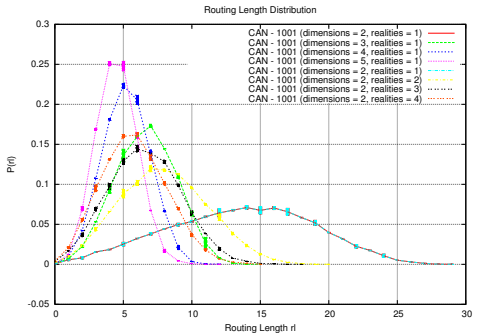
TECHNISCHE UNIVERSITÄT DARMSTADT

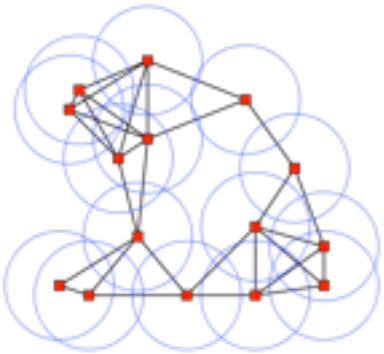
1. Extensability 
2. Run on regular desktop computers 
3. Evaluate networks with > 20.000 nodes 
4. Require less than 2 GB of memory 

7. Summary and Outlook

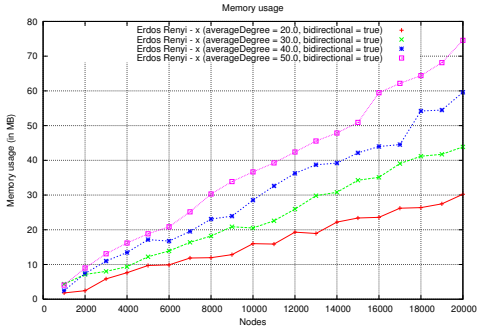
Summary and Planned Extensions to GTNA







```
public class MyNetwork extends NetworkImpl implements Network {
     private boolean p1;
     public MyNetwork(int nodes, boolean p1) {
          super("MY_NETWORK", nodes, new String[]{"P1"}, new String[]{"" + p1});
          this.p1 = p1;
     }
     public Graph generate(){
          Timer timer = new Timer();
          Node[] nodes = Node.init(this.nodes());
          Edges edges = new Edges(nodes, 100);
          for(int i=1; i<nodes.length; i++){
               edges.add(nodes[0], nodes[i]);
               if(this.p1)
                    edges.add(nodes[i], nodes[0]);
          }
          edges.fill();
          return new Graph(this.description(), nodes, timer);
     }
}
```



Summary

TECHNISCHE UNIVERSITÄT DARMSTADT

- Graph-theoretic analysis helps understand complex networks
- Often difficult task
  - adapting specific algorithms to special network formats
- GTNA - Graph-Theoretic Network Analyzer
  - Java-based framework
  - Easily extendable
  - Many network generators and metric implementations exist

Outlook

TECHNISCHE UNIVERSITÄT DARMSTADT

- Implementing additional metrics
- Providing Internet topology generators
- Analysis of network dynamics
- Graphical user interface

GTNA

A Framework for the Graph-Theoretic Network Analysis

Benjamin Schiller Dirk Bradler Immanuel Schweizer
Max Mühlhäuser Thorsten Strufe

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GTNA

Graph-Theoretic Network Analyzer