Gallager-Humblet-Spira (GHS) Algorithm in WSN

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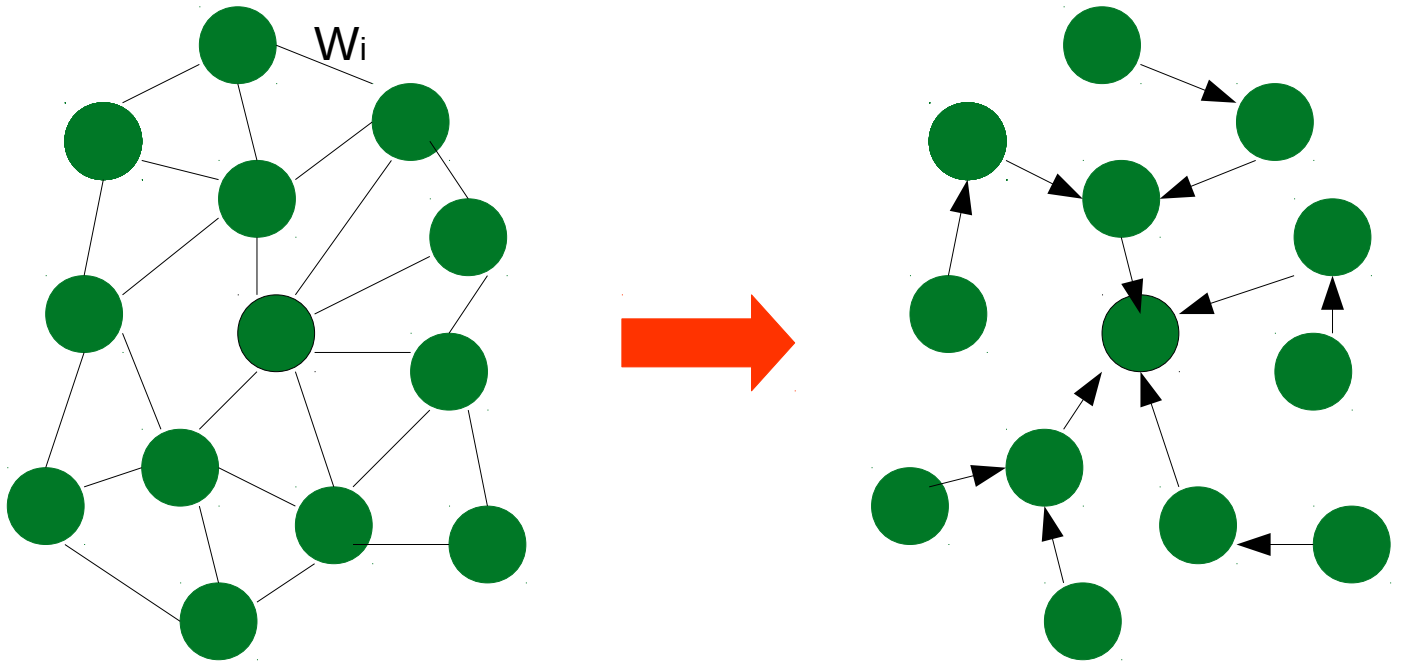
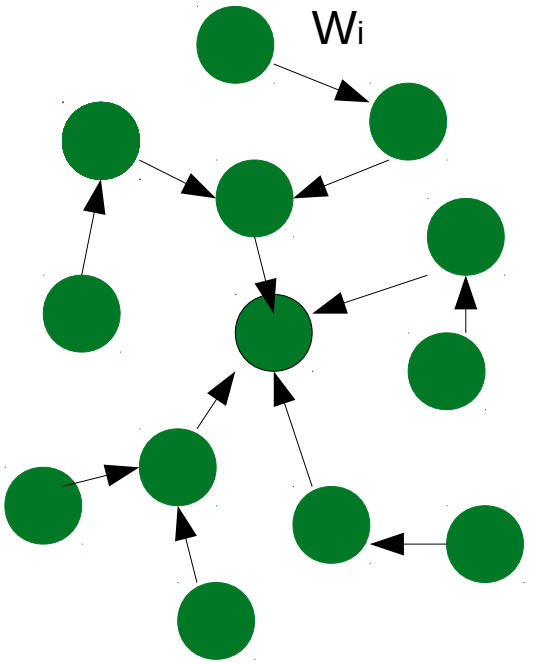
GHS Algorithm - Problem Statement

- Given a graph **G** with **N** nodes and **E** edges, find the Minimum Spanning Tree (MST)
- Minimum Spanning Tree
  - It includes all of the vertices of **G,** and
  - the sum of the weights of its edges is minimal.



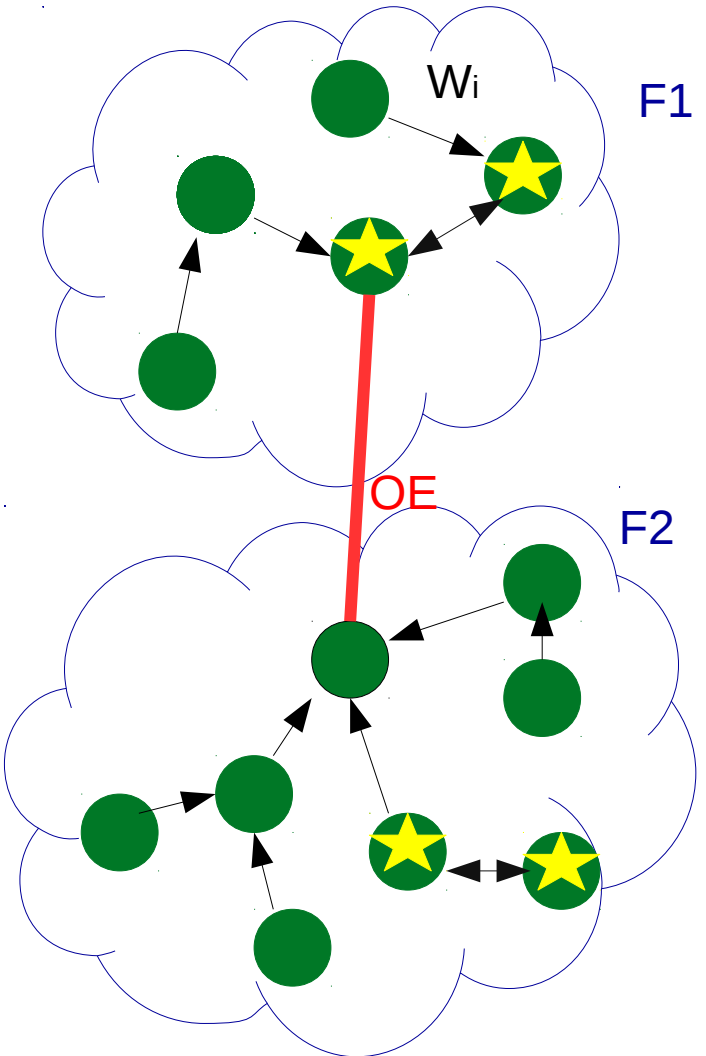
GHS Algorithm - Overview

- **Assumes**: Each node already knows the weight of each edge.
- Distributed algorithm for constructing a MST
- **Functioning**:
  - Sending msg over adjoining links,
  - Waiting for incoming msg, and
  - Processing
- **Characteristics**:
  - Asynchronous
  - Deadlock-free
  - Tolerates unpredictable but finite delay
  - One message contains at most
    - One edge weight + $\log_2 8N$ bits
  - Worst-case message complexity:
    - O(E + N log N): It is optimal



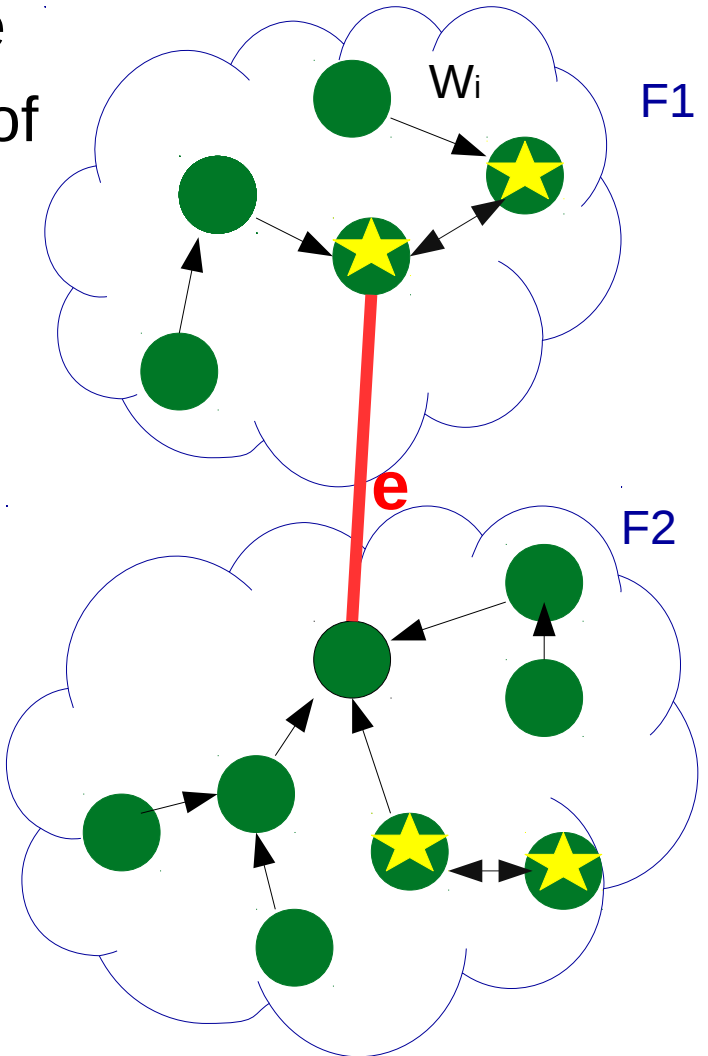
GHS Algorithm – Concepts (1)

- **Fragment (F)**: Any connected subgraph of the MST
  - **Core Nodes:**
    - Central Computing unit of the fragment
    - Receives reports of the lowest-weight edge
    - The join to another fragment is initiated
- **Outgoing Edge:** If exactly 1 of the nodes connected by the edge is in the fragment.
- **Type of messages:**
  - **Connect:** Request a connection to another F
  - **Initiate:** Initiate connection with another F
  - **Test:** Test whether the edge is an outgoing edge
  - **Accept:** Accept the edge as an outgoing edge
  - **Reject:** Reject the edge as an outgoing edge
  - **Report:** To report the lowest-weight of a node
  - **Change Root:** Change the core nodes of the fragment.



GHS Algorithm – Concepts (2)

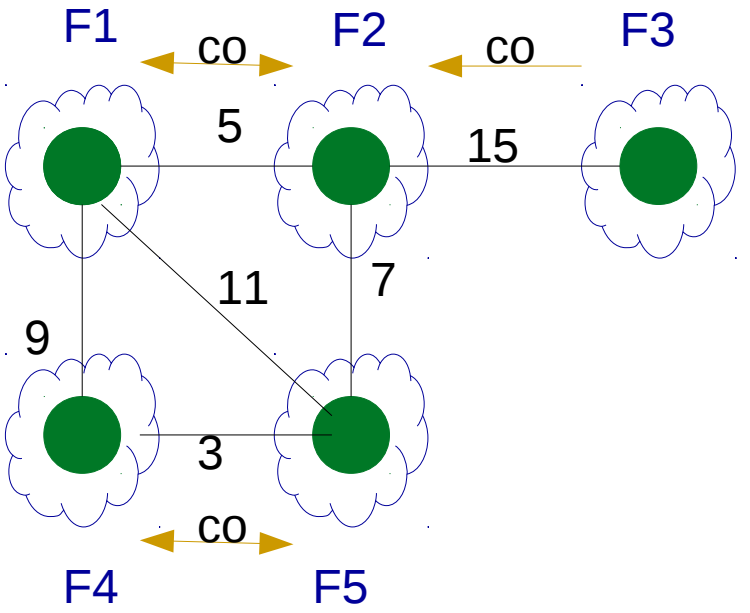
- GHS algorithm is built on the following property
  - **Property:**
    - Given a fragment of an MST, let **e** be a **minimum-weight outgoing edge** of the fragment.
    - Then joining **e** and its adjacent nonfragment node to the fragment yields another fragment of an MST.



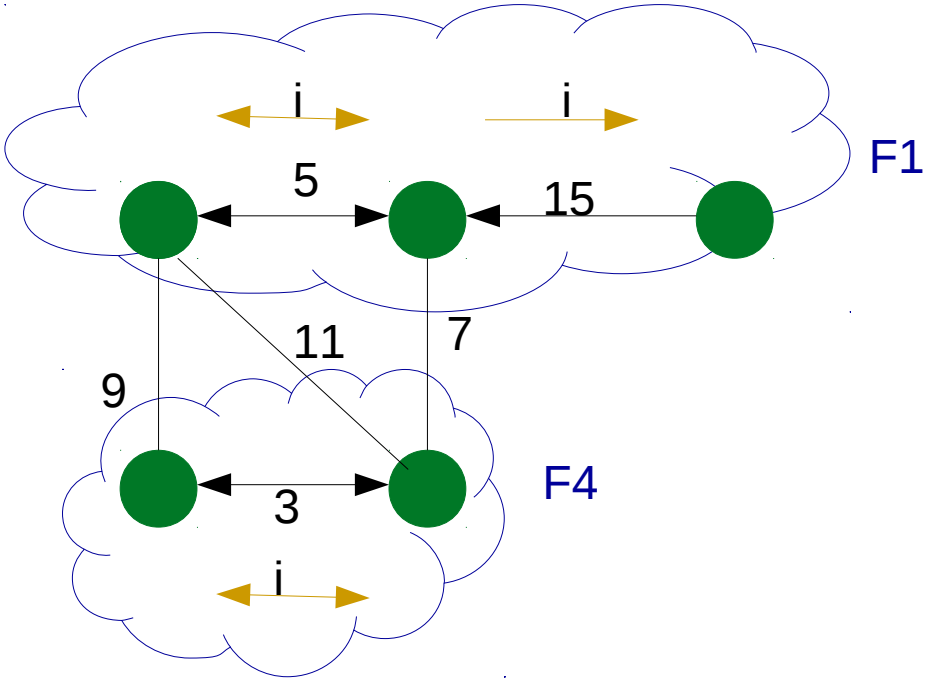
- We can join fragment F1 with F2 as long as e is a **minimum-weight outgoing edge**.
- By joining fragments the MST is found.

GHS Algorithm – Example

- **Initially (Connect):**
  - Each node belongs to a different fragment
  - Each node sends a Connect **(co)** msg via its lowest-weight edge

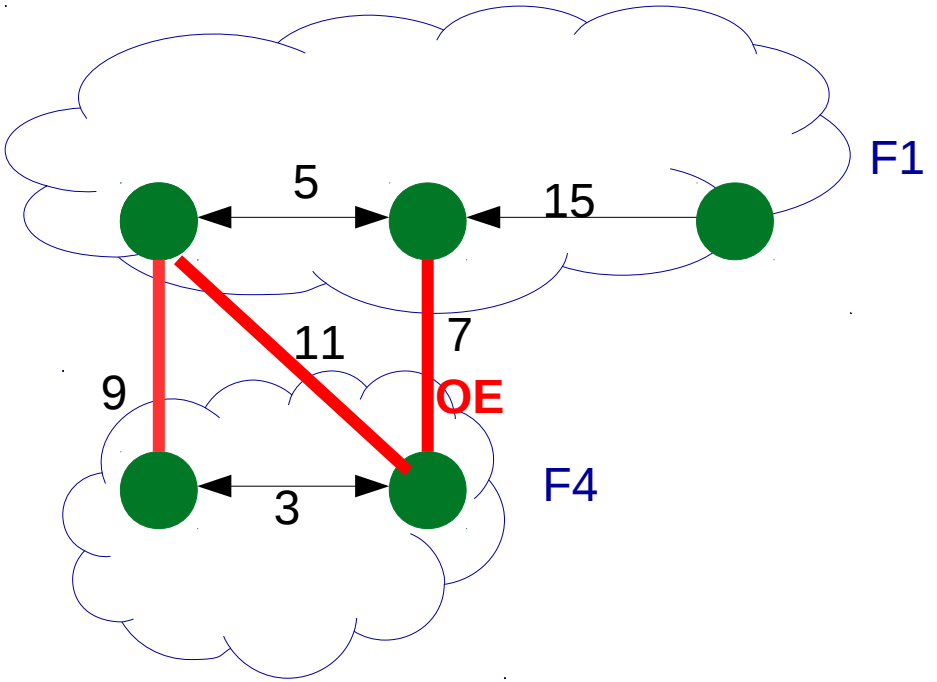


- **Initiate:**
  - Each node responds a Connect msg with an initiate (i) msg.
  - Then, the Fs that received an i msg merge.
  - At the reception of an initiate msg the node selects the sender as its parent

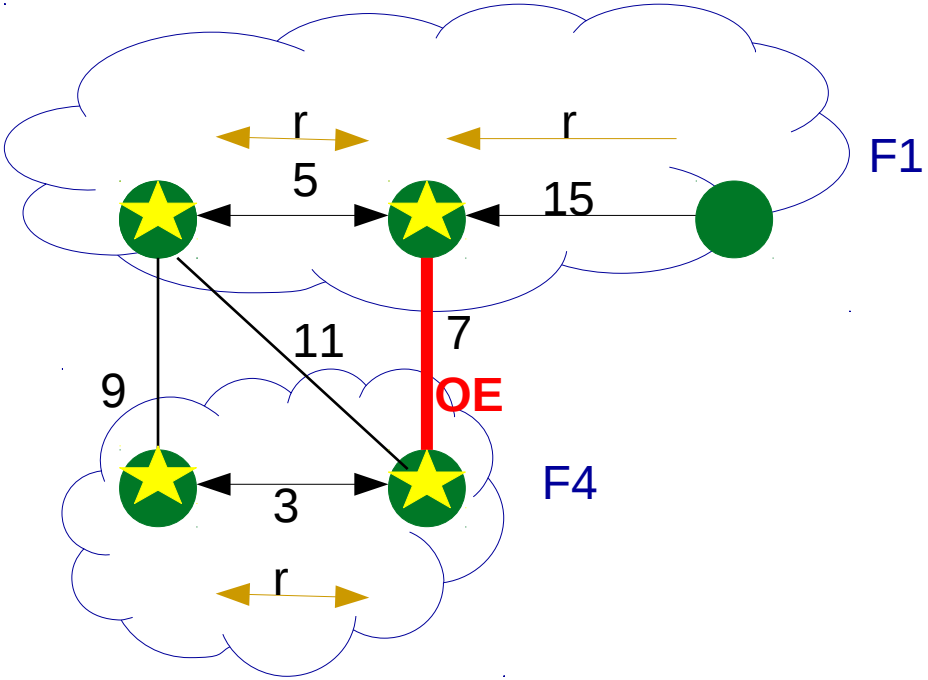


GHS Algorithm – Example

- **Test: Accept or Reject:**
  - Each node sends test (t) msg to find the outgoing edges (**OE**)
  - The edge is **accepted** if it belongs to a different fragment
  - The edge is **rejected** if it belongs to the same fragment

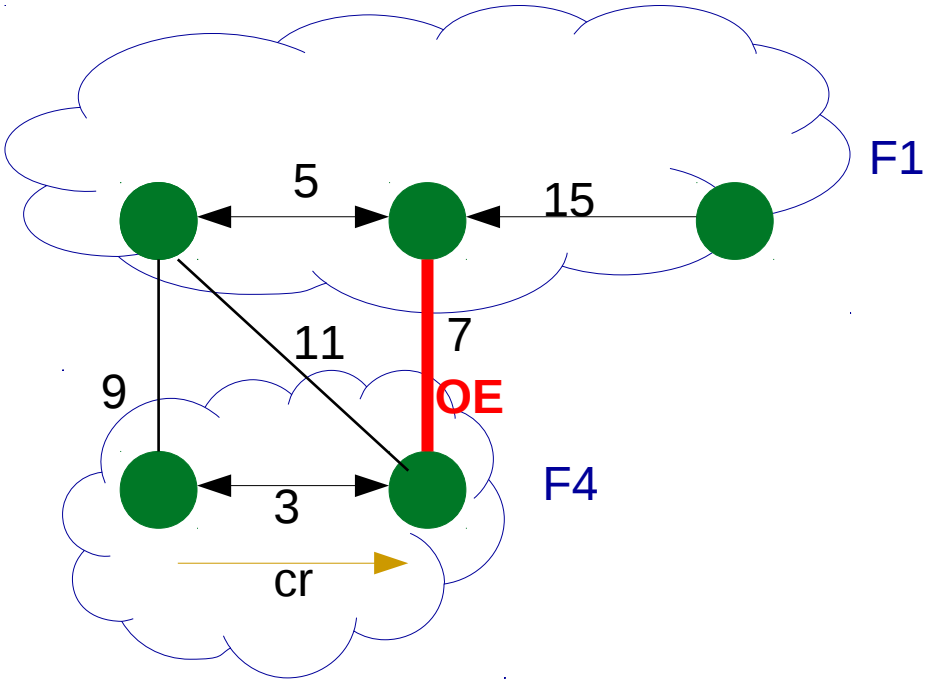


- **Report:**
  - Each node reports its lowest weight outgoing edge.
  - The **core nodes** process the report msg and find the *lowest weight outgoing edge* of the fragment.

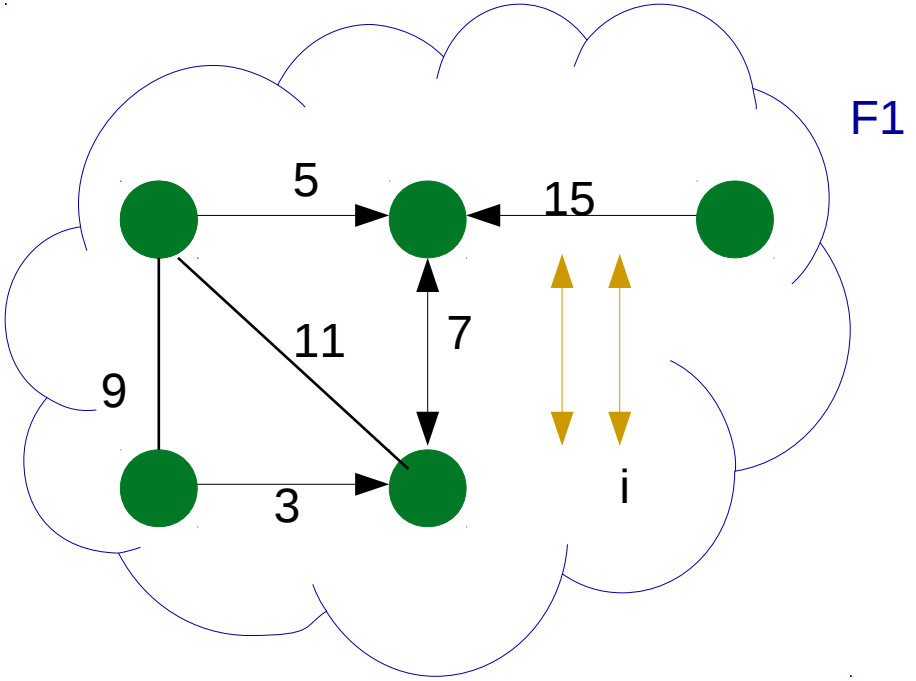


GHS Algorithm – Example

- **Change Root:**
  - A Change root msg is sent to the node that owns the *lowest weight outgoing edge* in each fragment.

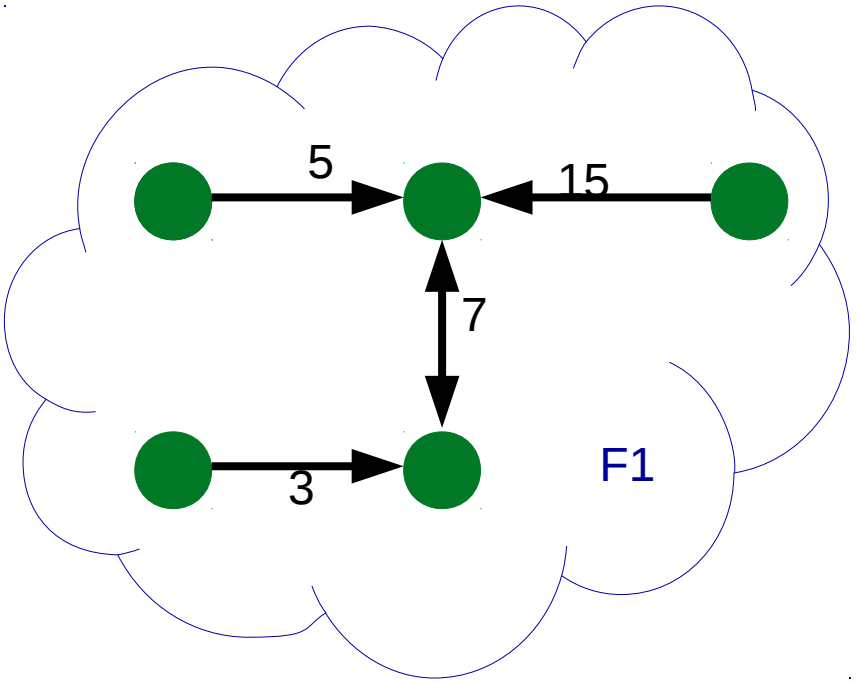


- **Connect:**
  - The fragments send a connect msg, followed by a initiate msg.
  - The fragments joined together
  - The nodes change their parent according to the last initiate msg.



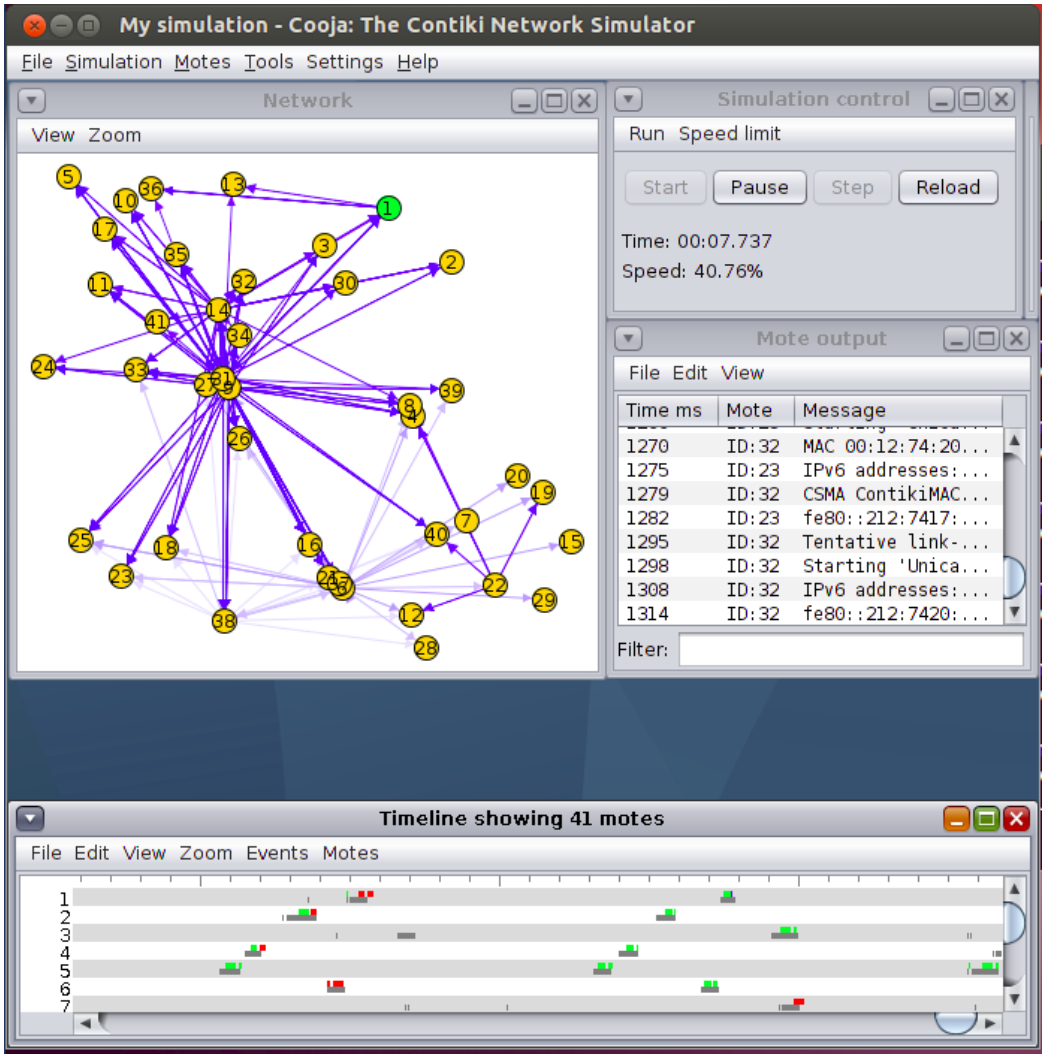
GHS Algorithm – Example

- **Final result:**
  - Only one fragment remains
  - Minimum Spanning Tree
  - Each node has a parent
  - The more costly edges are avoided



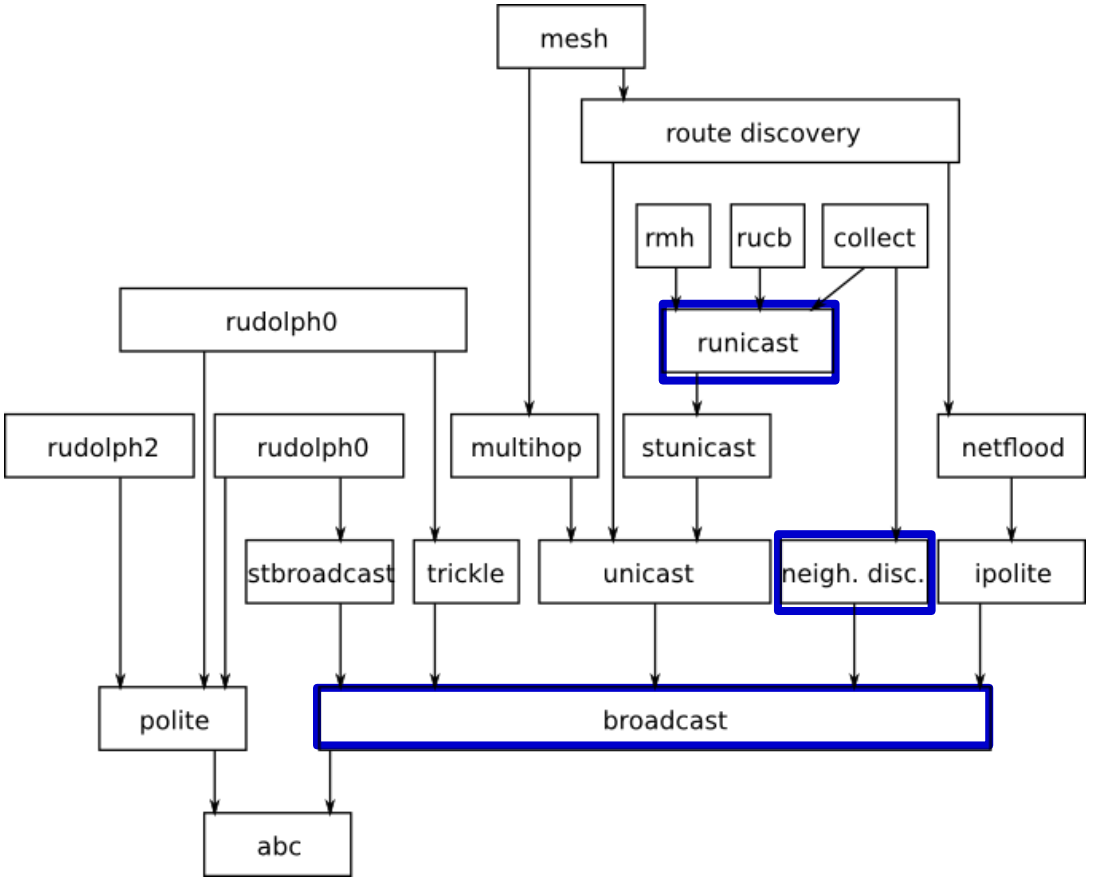
GHS implementation in Contiki OS - Overview

- **Contiki Characteristics**:
  - It is an open source Operating System for IoT.
  - It is event-driven and it is written in C
  - The protocol stack can be chosen between
    - IPv4
    - IPv6
    - **Rime**: We selected rime to implement the GHS algorithm.

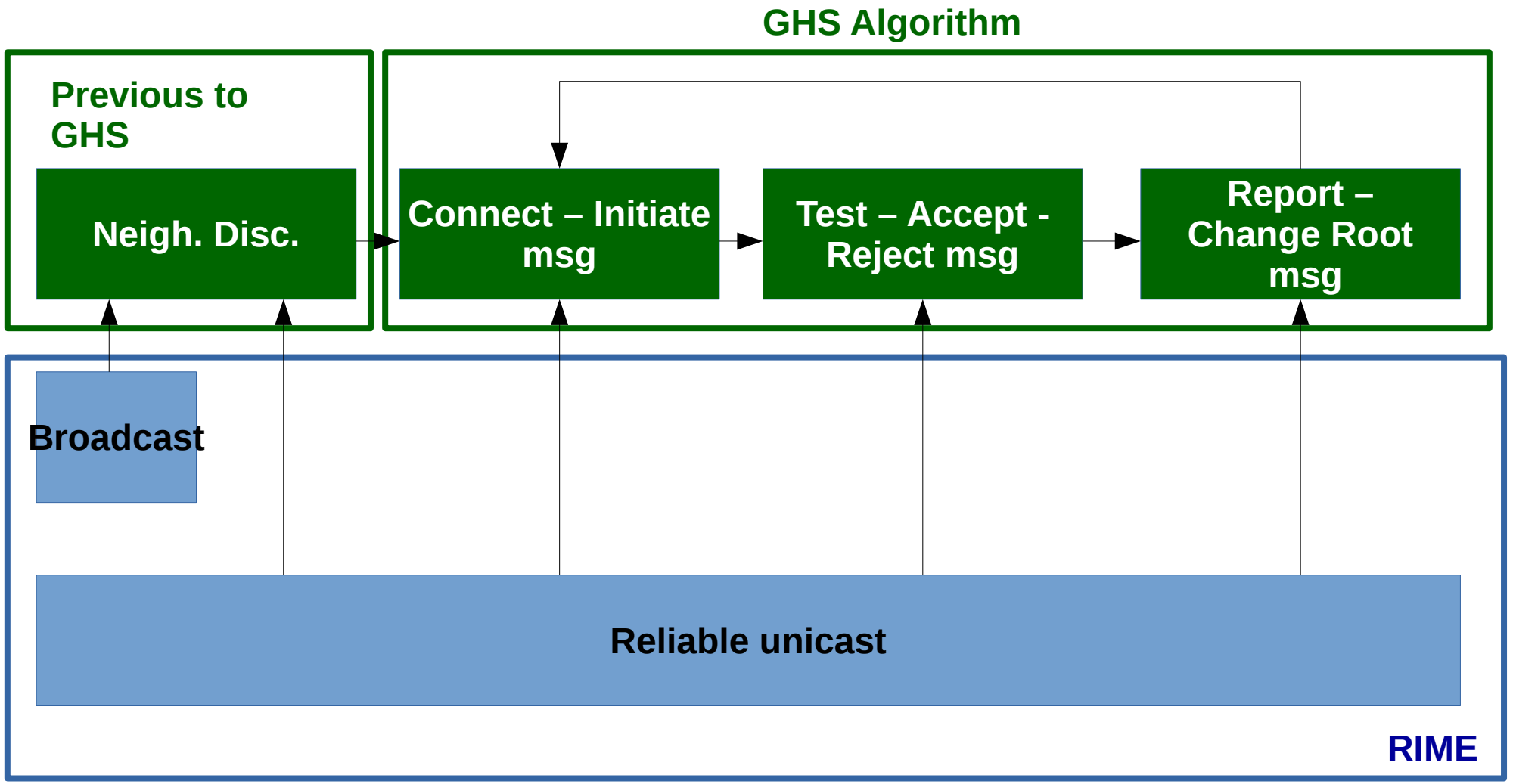


GHS implementation in Contiki OS - Rime

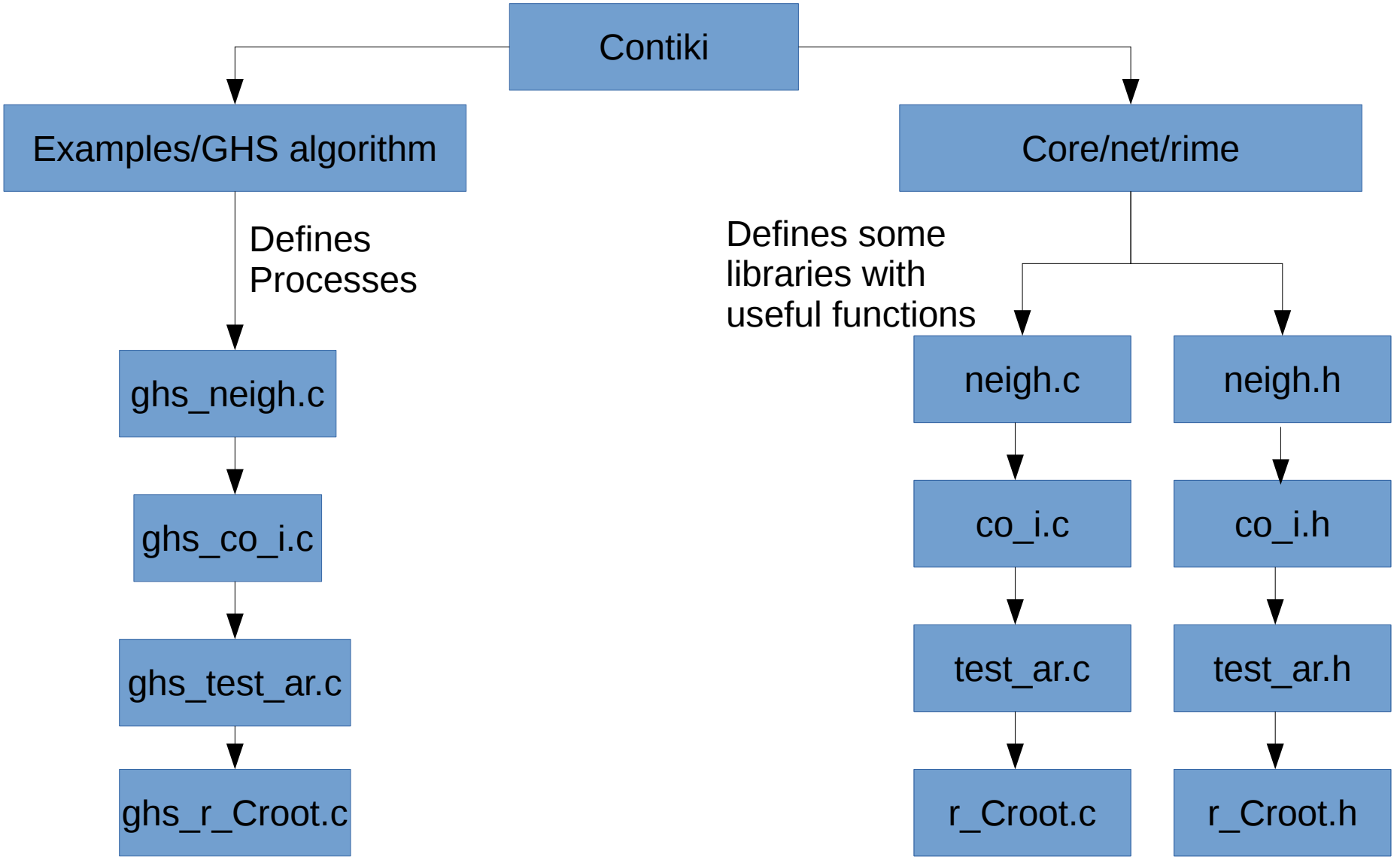
- **Rime**:
  - It provides a hierarchical set of wireless network protocols
  - It provides from a simple anonymous broadcaster to a mesh network routing



GHS implementation in Contiki OS - Rime

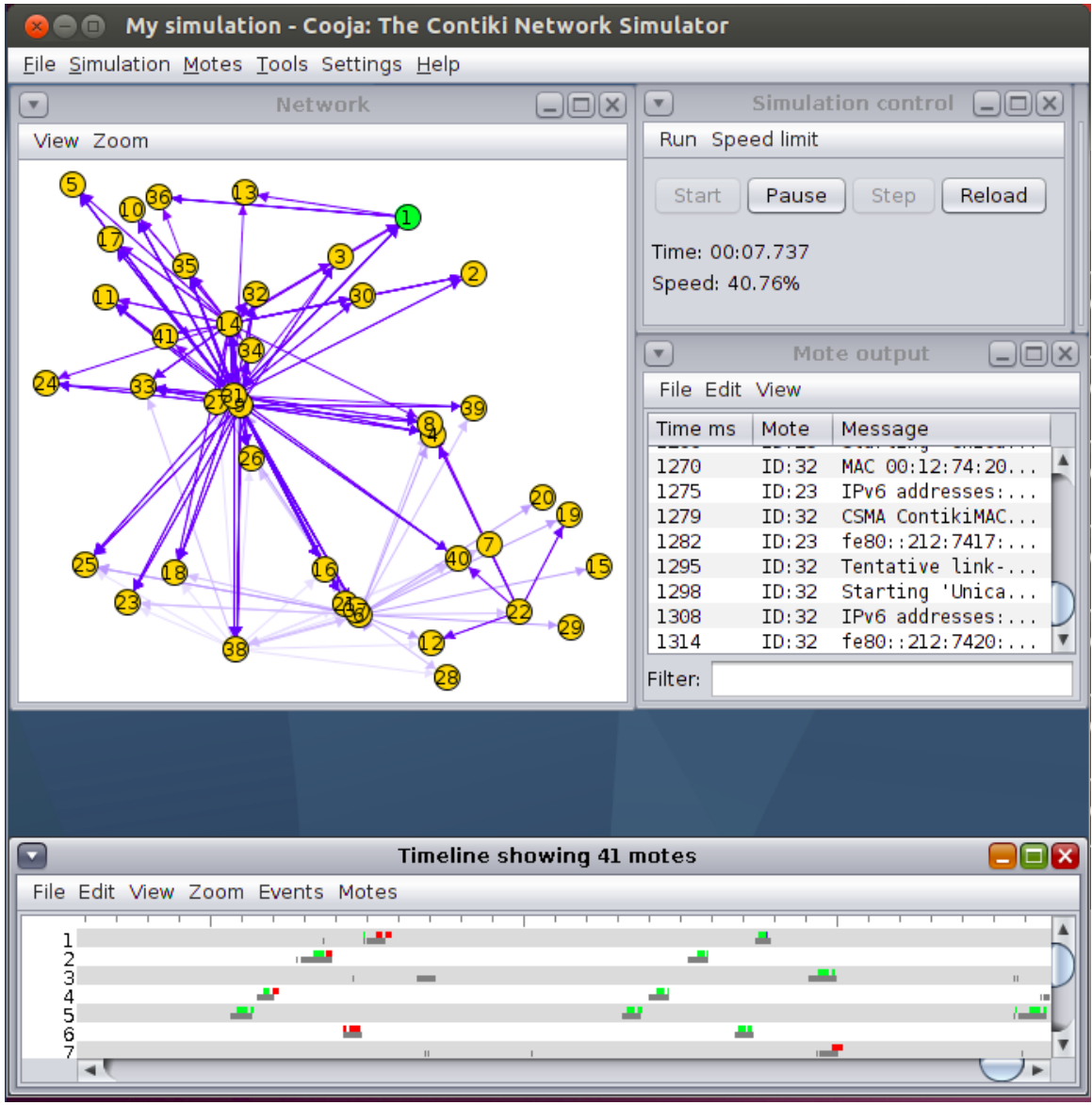


GHS implementation in Contiki OS - Rime



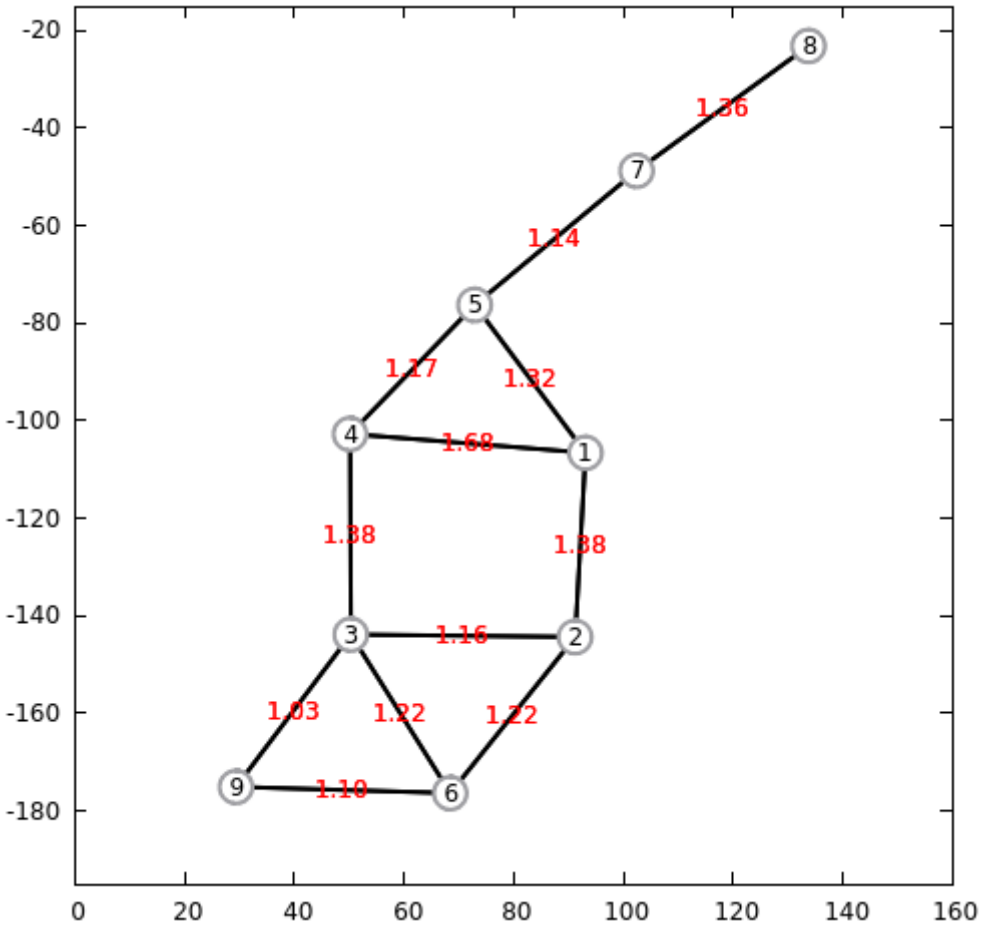
GHS implementation in Contiki OS - Cooja

- **Cooja**
  - It is the Contiki network emulator.
  - A simulated node in Cooja is an actual compiled and executing Contiki system.

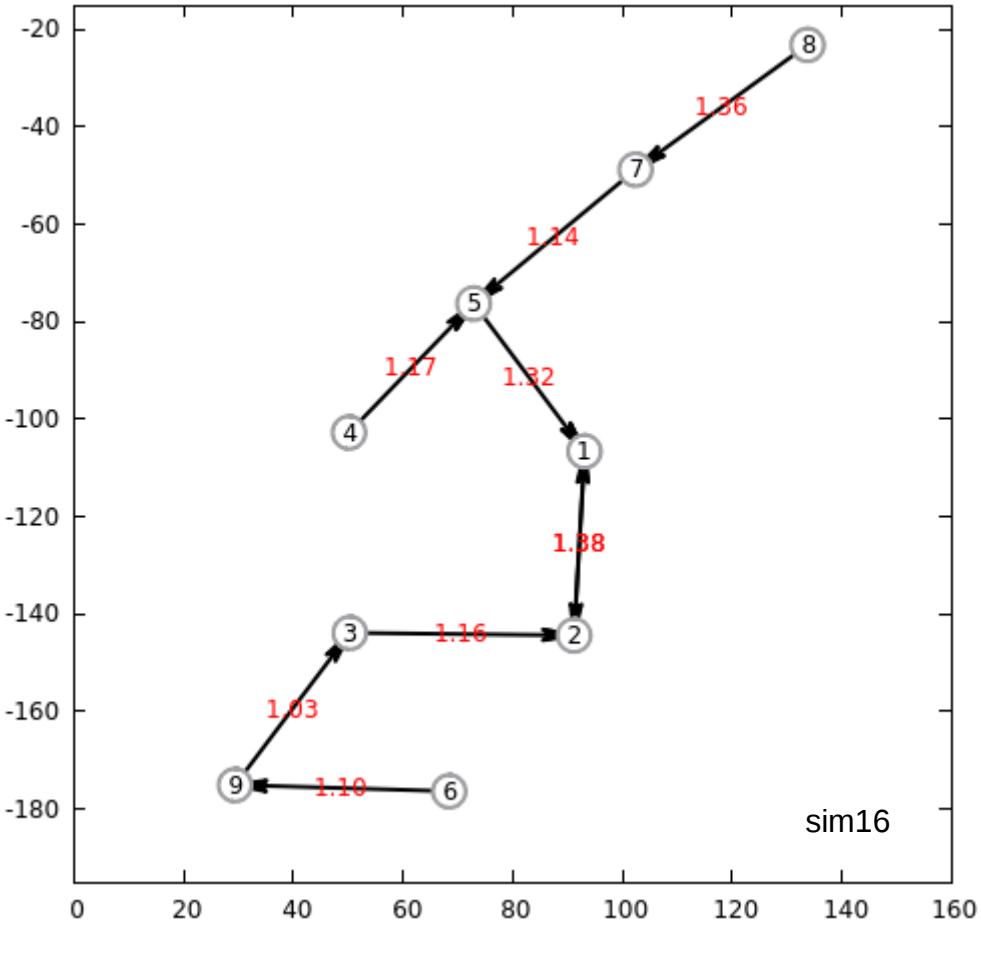


GHS Results

Graph



Minimum Spanning Tree



GHS Results

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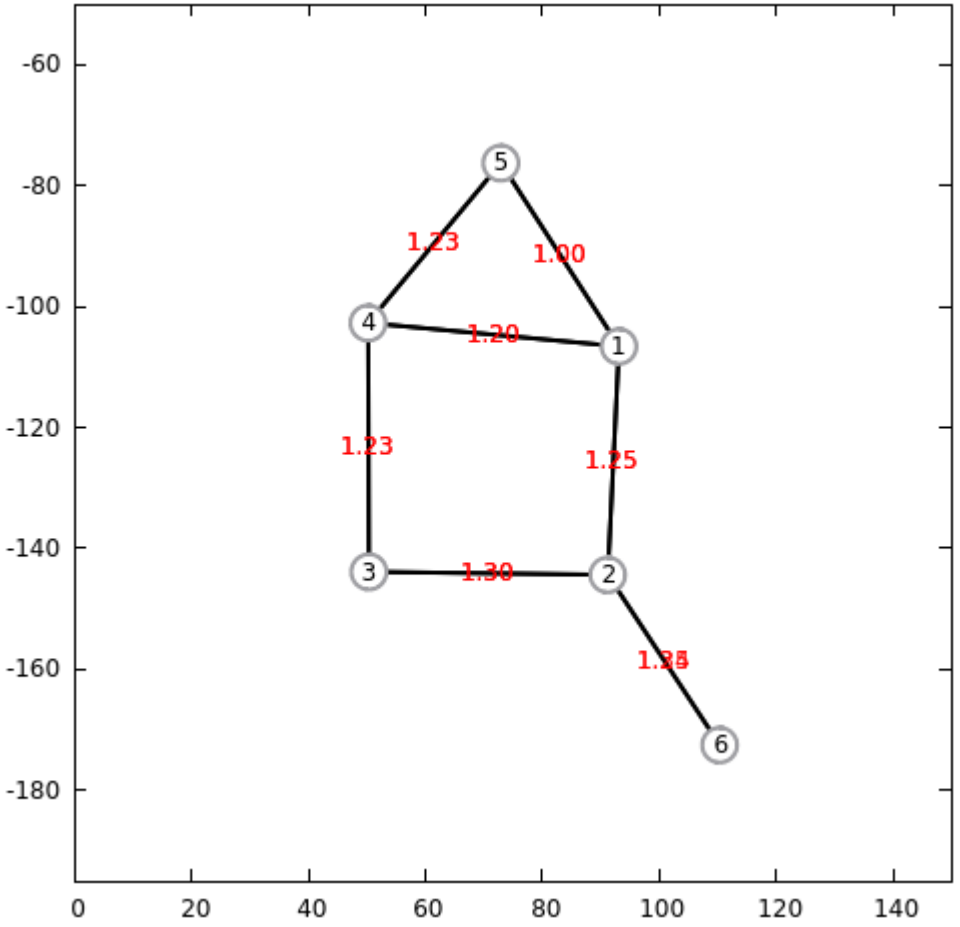

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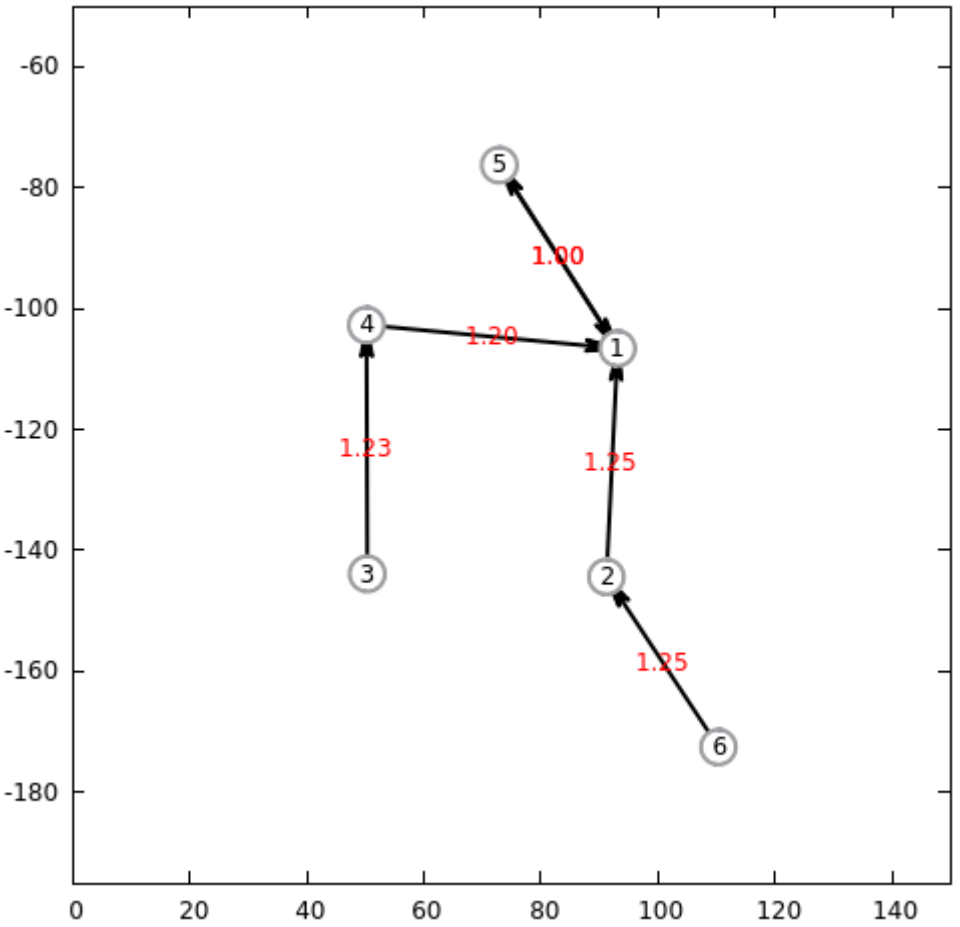

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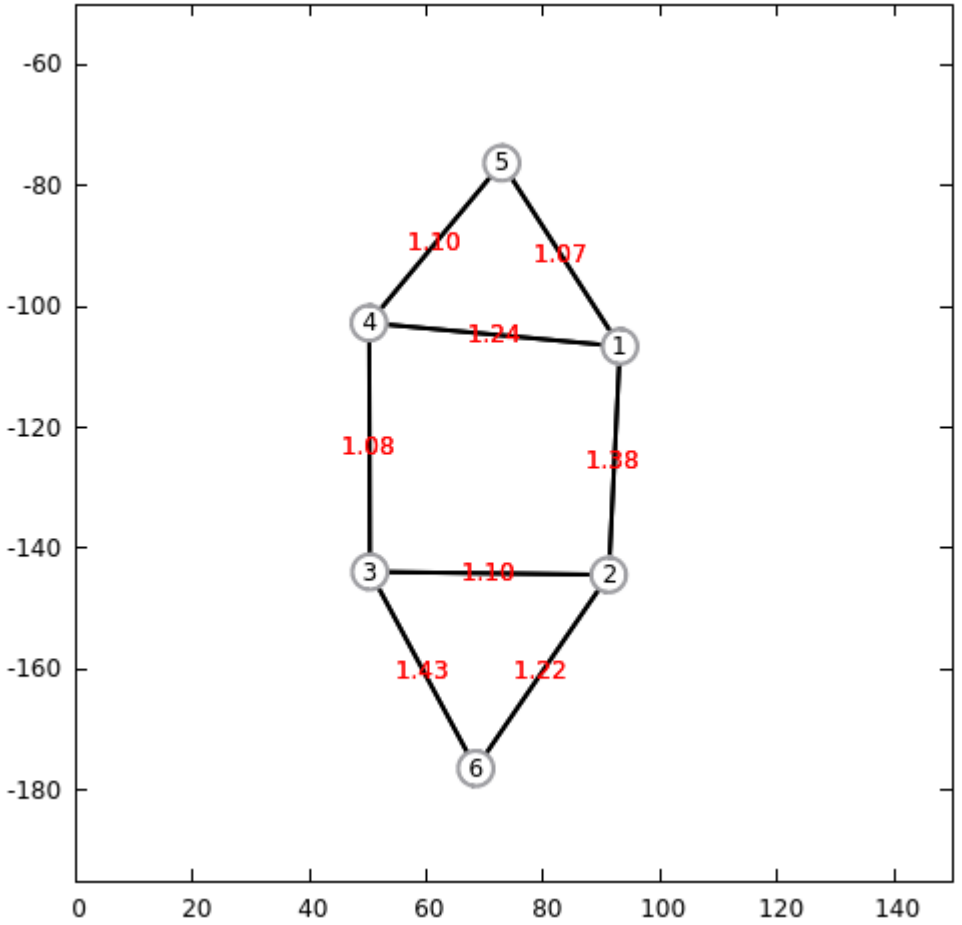

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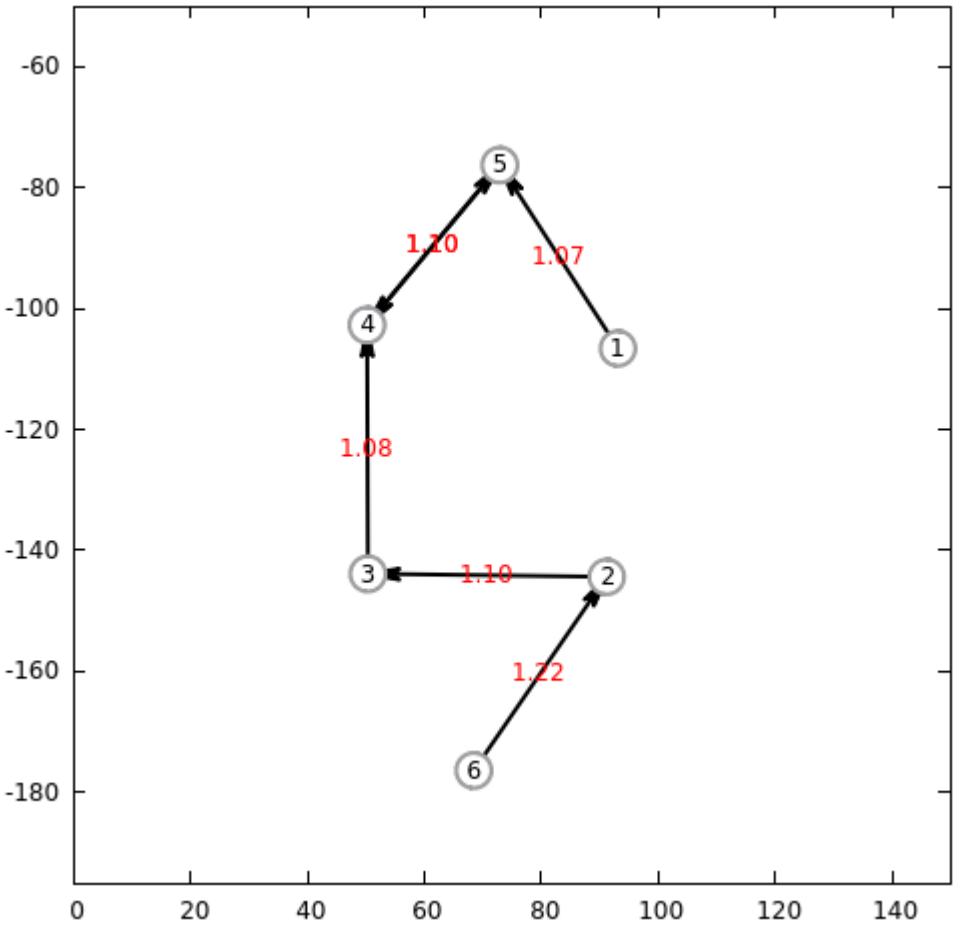

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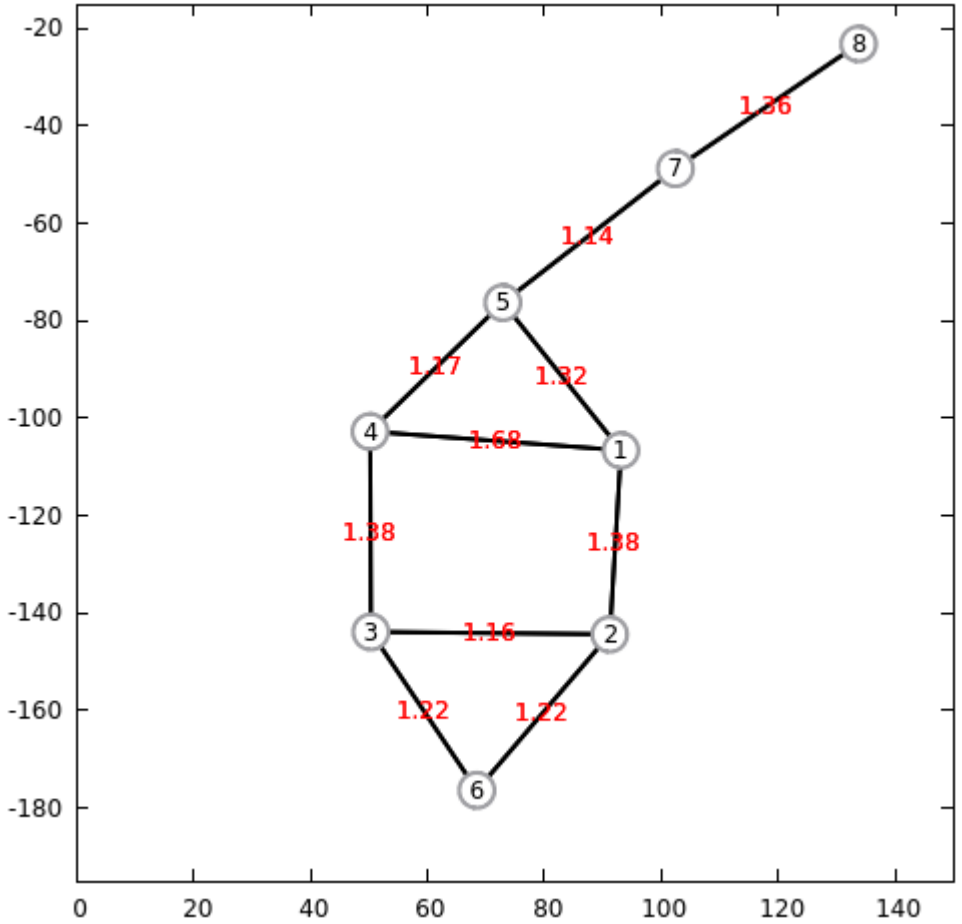

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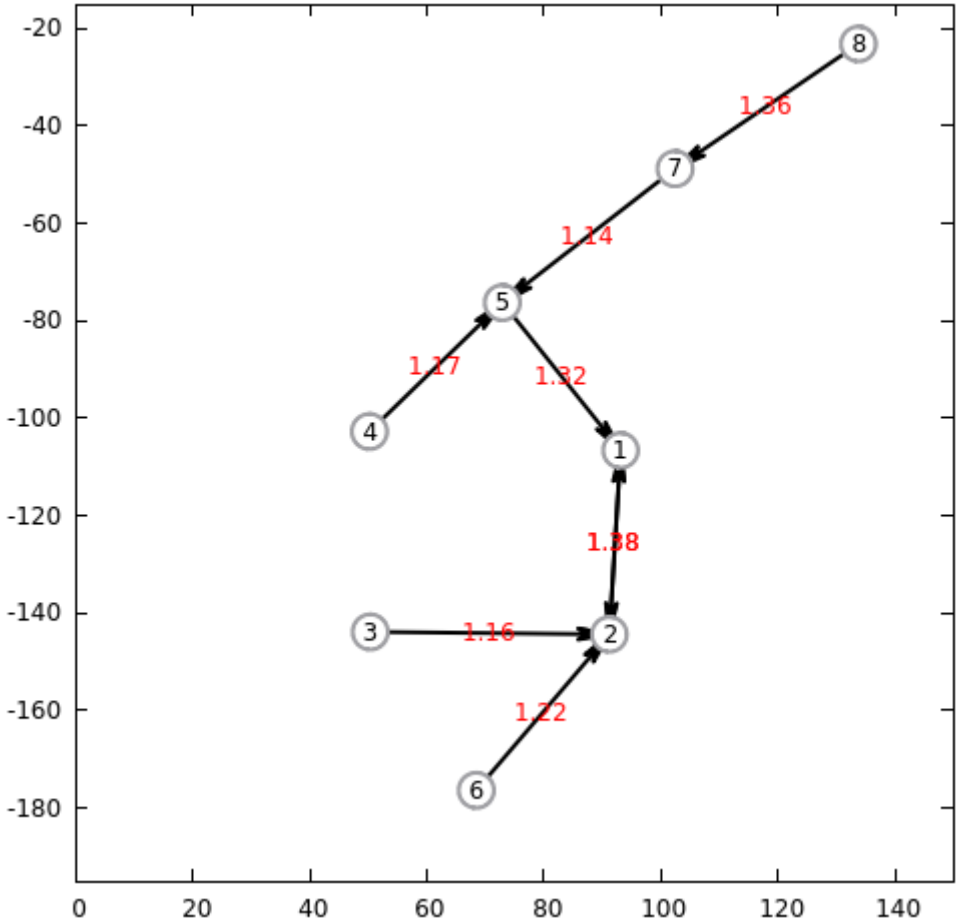

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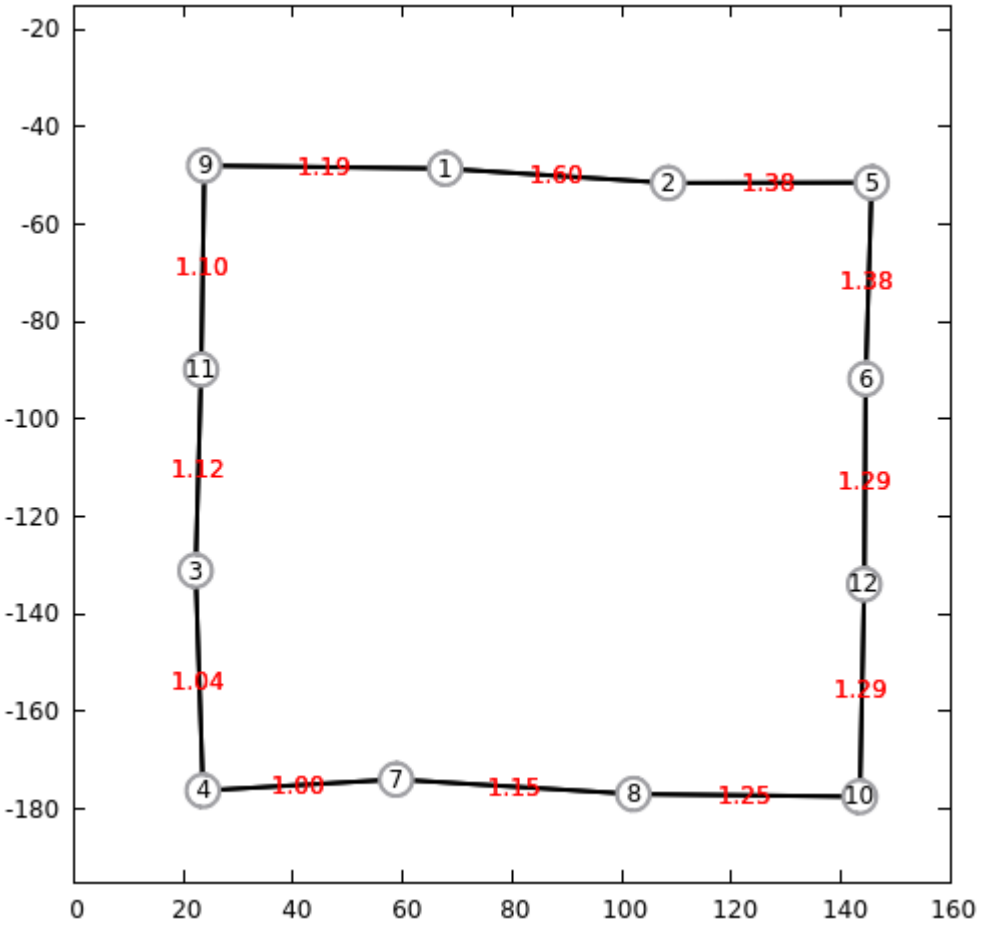

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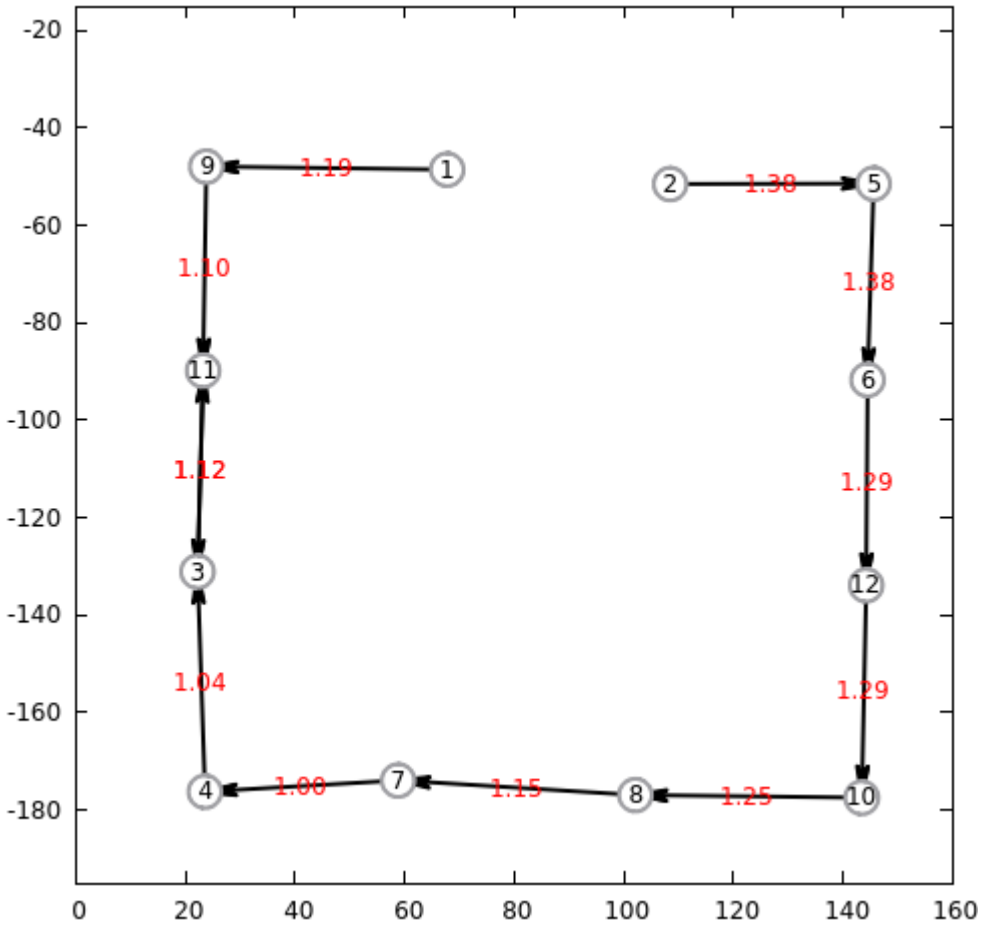


ANY
QUESTIONS?