On Network Model Division Method based on Link-to-Link Traffic Intensity for Accelerating Parallel Distributed Simulation

Hiroyuki Ohsaki

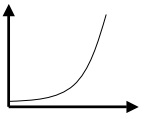
Graduate School of Information Science and Technology
Osaka University, Japan

Background

- Increasing size and complexity of the Internet
- Demand for evaluation technique of large-scale networks
- Strongly required to...
  - Ensure reliability, safety, and robustness
  - Allow future network expandability
  - Assess impact of terrorism and natural disasters

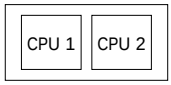
Conventional Techniques for Performance Evaluation

- Analysis techniques
  - e.g., Queuing theory
    - # of states exponentially increases as # of nodes increases
- Simulation techniques
  - A huge amount of computing resources is required
- Both techniques are...
  - Not applicable to large-scale networks



Parallel Simulation

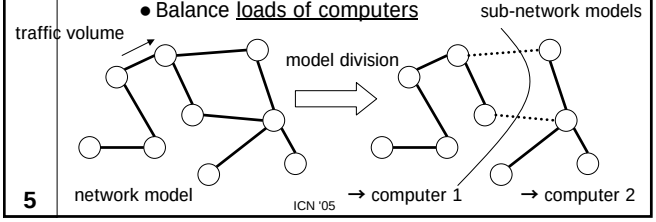
- May allow simulation of large-scale networks
- Network simulators that support parallel simulation
  - QualNet, OPNET
    - Run on a single SMP computer
    - Not run on multiple computers
  - PDNS (Parallel Distributed NS)
    - Run on multiple computers
    - Have only limited features
      - Simulation is very slow due to communication overhead



single SMP computer

Research Objective

- Accelerate parallel distributed simulation
  - by proposing a network model division method
    - Minimize communication overhead
    - Balance loads of computers



Basic Ideas of Our Network Model Division Method

- In a packet-level simulation...
  - Communication overhead and computational load should be proportional to traffic volume
- 1. Perform steady state analysis
  - Estimate traffic volume on each link in steady state
- 2. Divide network model into two sub-network models
  - Divide at links with least traffic volume while...
    - Balancing loads of two sub-network models
- 3. Repeatedly divide the largest sub-network model

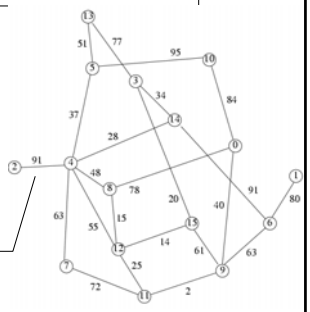
Network Model Division Method

- 1. Perform steady state analysis
  - Derive traffic volume on each link in steady state
- 2. Obtain candidates of a network model division
  - Use intermediate results of a min-cut algorithm
- 3. Apply the network model division with...
  - Smallest cut capacity (= communication overhead)
  - Most balanced total traffic volumes
- 4. Repeatedly divide the largest sub-network model
  - Repeat steps 2 and 3 for a sub-network model with the largest total traffic volume

Example of Network Model Division

- Network model
  - # of nodes: 16
  - Average degree: 3
  - Link bandwidth: 1-100 [Mbit/s]
  - Link propagation delay: 10-200 [ms]
- Randomly generated 100 TCP connections

bandwidth in Mbit/s



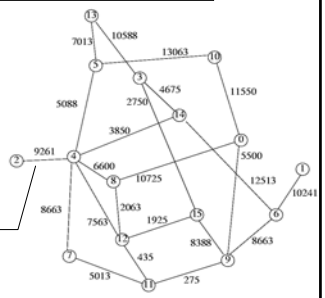
Network Model Division Method

- 1. Perform steady state analysis
  - Derive traffic volume on each link in steady state
- 2. Obtain candidates of a network model division
  - Use intermediate results of a min-cut algorithm
- 3. Apply the network model division with...
  - Smallest cut capacity (= communication overhead)
  - Most balanced total traffic volumes
- 4. Repeatedly divide the largest sub-network model
  - Repeat steps 2 and 3 for a sub-network model with the largest total traffic volume

Example of Network Model Division (Step 1)

- 1. Perform steady state analysis
  - Derive traffic volume on each link in steady state

estimated traffic volume in Kbyte/s



Network Model Division Method

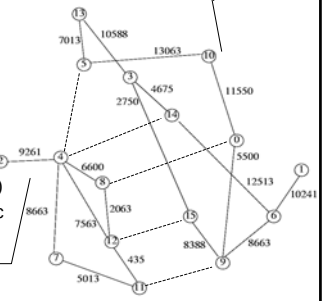
- 1. Perform steady state analysis
  - Derive traffic volume on each link in steady state
- 2. Obtain candidates of a network model division
  - Use intermediate results of a min-cut algorithm
- 3. Apply the network model division with...
  - Smallest cut capacity (= communication overhead)
  - Most balanced total traffic volumes
- 4. Repeatedly divide the largest sub-network model
  - Repeat steps 2 and 3 for a sub-network model with the largest total traffic volume

Example of Network Model Division (Steps 2 and 3)

total traffic volume = 94,944KB/s

- 2. Obtain candidates of a network model division
  - Use intermediate results of a min-cut algorithm
- 3. Apply the network model division with...
  - Smallest cut capacity (= communication overhead)
  - Most balanced total traffic volumes

total traffic volume = 39,598KB/s

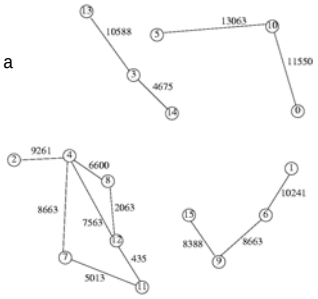


Network Model Division Method

- 1. Perform steady state analysis
  - Derive traffic volume on each link in steady state
- 2. Obtain candidates of a network model division
  - Use intermediate results of a min-cut algorithm
- 3. Apply the network model division with...
  - Smallest cut capacity (= communication overhead)
  - Most balanced total traffic volumes
- 4. Repeatedly divide the largest sub-network model
  - Repeat steps 2 and 3 for a sub-network model with the largest total traffic volume

Example of Network Model Division (Step 4)

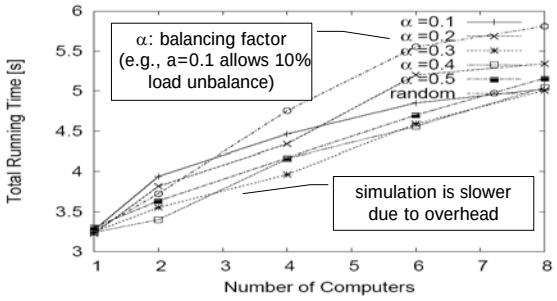
- 4. Repeatedly divide the largest sub-network model
  - Repeat steps 2 and 3 for a sub-network model with the largest total traffic volume



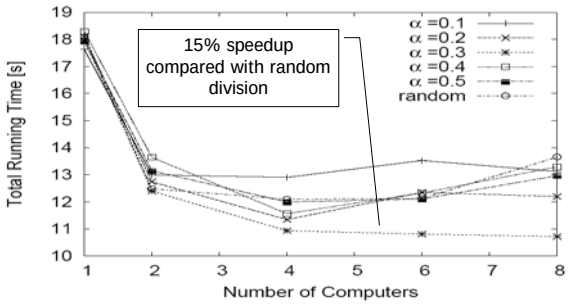
Features of Our Network Model Division Method

- Advantages
  - Minimize communication overhead among computers running parallel simulation
  - Balance loads of sub-network models
- Disadvantages
  - Cannot handle bursty traffic since...
    - Steady state analysis assumes persistent TCP and UDP traffic

Experimet Results (10 nodes and 10 TCP connections)



Experimet Results (100 nodes and 100 TCP connections)



Conclusion

- Proposed a heuristic network model division method
  - To accelerate parallel distributed simulation
    - Minimize communication overhead
    - Balance loads of computers
  - Basic ideas
    - Esitimate traffic volume by steady state analysis
    - Utilize intermediate results of a min-cut algorithm

Future Works

- Improve our network model division method
  - Support bursty TCP and UDP traffic
  - Support multicast traffic