A distributed measurement method for reducing measurement conflict frequency in overlay networks

Dinh Tien HOANG, Go HASEGAWA, Masayuki MURATA
Osaka University, Japan

Measurement conflict in overlay networks

- Overlay networks
  - Logical network constructed on the underlay network
- Network resource information
  - Available bandwidth, delay, packet loss, etc
  - Essential for maintenance and improvement of the performance of network service
- Should be measured frequently

Measurement conflict problem

- Happens when overlapping paths are measured concurrently
- Causes measurement error, link stress

Existing measurement method[1] (1/2)

- Measurement overhead is concentrated at a master node
  - Aggregating topology information
  - Determining measurement timing
  - Giving instructions to overlay nodes
  - Receiving measurement results

The amount of time and network traffic for aggregation of topology information and measurement results is large


Existing measurement method[1] (2/2)

- Measurement conflicts avoiding algorithm
  - The measurement tasks are divided into several groups
  - Measurement tasks of paths that do not overlap with each other are included in the same group
  - Tasks in same group are executed concurrently
  - Tasks in different groups are executed sequentially

Measurements conflict can be avoided completely

- Task groups are obtained using a heuristic algorithm
  - Number of task groups may become large

This method can not measure with high frequency

Overview of our measurement method

- A distributed traceroute-like measurement method
  - Each overlay node detects overlapping state of overlay paths it measures
  - Each overlay node determines the measurement frequency and measurement timing of overlay paths to avoid measurement conflict

- High measurement frequency
  - Only reduce measurement frequency if necessary to avoid measurement conflict

Outline of our measurement method

- Classify overlapping states
  - Complete overlapping
  - Half overlapping
  - Partial overlapping

- Reduce measurement paths
  - Reduce measurement conflict of complete overlapping paths
  - Reduce measurement conflict of half overlapping paths
  - Reduce measurement conflict of partial overlapping paths
Path overlapping classification

- **Complete overlapping**: One path completely includes another path
  - Can be detected by traceroute

- **Half overlapping**: Two paths share a route from the source overlay node to a router that is not an overlay node
  - Can be detected by traceroute

- **Partial overlapping**: Two paths share a route that does not include overlay nodes
  - Can not be detected by traceroute

Outline of our measurement method

- Classify overlapping states
  - Complete overlapping
  - Half overlapping
  - Partial overlapping

- Detect overlapping paths
  - Reduce measurement conflict
    - Avoid measurement conflict of complete overlapping paths
    - Avoid measurement conflict of half overlapping paths
    - Reduce measurement conflict of partial overlapping paths

Detecting partial overlapping paths

- How can A detect partial overlapping paths of AB?
  - Issues traceroute to other overlay nodes
Detecting partial overlapping paths

- Issues traceroute to other overlay nodes
- Detects half overlapping paths
- Infers partial overlapping paths

How can A detect partial overlapping paths of AB?

Outline of our measurement method

- Classify overlapping states
  - Complete overlapping
  - Half overlapping
  - Partial overlapping
- Detect overlapping paths
- Reduce measurement conflict
  - Avoid measurement conflict of complete overlapping paths
  - Avoid measurement conflict of half overlapping paths
  - Reduce measurement conflict of partial overlapping paths

Measurement conflict avoiding method for complete overlapping paths

- Complete overlapping path is not measured directly
- The measurement result is estimated based on the measurement results of shorter overlay paths [2]
  - Example: delay of AC = delay of AB + delay of BC

Measurement frequency

\[
\text{Measurement frequency} = \frac{\text{Measurement time}}{\text{Measurement duration}}
\]

Measurement conflict avoiding method for half overlapping paths (1/2)

- Calculate measurement frequencies according to the degree of fluctuation of measurement results

Measurement conflict avoiding method for half overlapping paths (2/2)

- Adjust measurement frequencies so that A can measure AB and its half overlapping paths sequentially.
- The sum of measurement frequencies must be smaller or equal to one (\( \sum_{i=1}^{K} \alpha_i = 1 \))
  - If \( \alpha_1 + \ldots + \alpha_K > 1 \), reduce the measurement frequencies.
  - The reduction rates should be the same.
  - The reduction of frequencies should be as small as possible.

\[
\beta_i = \frac{\alpha_i}{\alpha_1 + \alpha_2 + \ldots + \alpha_K}
\]

Outline of our measurement method

- Classify overlapping states
  - Complete overlapping
  - Half overlapping
  - Partial overlapping
- Detect overlapping paths
- Reduce measurement conflict
  - Avoid measurement conflict of complete overlapping paths
  - Avoid measurement conflict of half overlapping paths
  - Reduce measurement conflict of partial overlapping paths

Measurement conflict reducing method for partial overlapping paths

- Measurement conflicts cannot be completely avoided.
  - Because partial overlapping paths are measured by different overlay nodes.
- Reduce probability of measurement conflict.
  1. Adjust measurement frequency of AB.
     - If path AB has K-1 partial overlapping paths, set the frequency of path AB to a value not greater than 1/K
     \[
     \gamma_i = \min\left(\frac{1}{K_i}, 1\right)
     \]
  2. Take the measurement timing of AB randomly.

Performance evaluation

- Evaluation metrics
  - Measurement execution ratio: average value of measurement frequencies of all overlay paths
  - Measurement success ratio: average value of frequencies of measurement tasks that do not conflict with other measurement tasks
- Network models
  - Underlay topology
    - AT&T
    - BA model (10 topologies)
    - Waxman model (10 topologies)
  - Overlay topology
    - Overlay nodes are chosen randomly
    - Density of overlay node: 0.05 – 0.4

Performance evaluation result (1/3)

AT&T topology

- Measurement execution ratio
- Success ratio

Performance evaluation result (2/3)

BA topology

- Measurement execution ratio
- Success ratio

Copyright © 2019

12.2.23
Conclusions and future works

**Conclusions**
- Proposed a distributed overlay network measurement method that reduces the probability of measurement conflicts
- Infer the overlapping of paths
- Adjust the measurement frequency and the measurement timing of paths

**Future works**
- Evaluation of measurement overhead
- Construction of measurement system

Thank you for your attention!