The Joint Optimization of Online Traffic Matrix Measurement and Traffic Engineering For Software-Defined Networks

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Introduction

- With the advent of software-defined networking (SDN), configurable, adaptable, and fine-grained traffic control is made possible. Flow tables are stored in Tenantry Content Addressable Memories (TCAM) of SDN switches.
- TCAM resources are scare.

Keywords

Traffic Matrix(TM), Traffic Matrix Measurement(TMM), Traffic Engineering(TE)

TM and TE

- Accurate TM estimation and TE helps in achieving improved performance and guarantee QoS requirements.
- Direct measurement of TMs on large-scale networks requires large amount of resources. E.g: NetFlow, sFlow
- Indirect measurement of TM suffer from high estimation error.
- A hybrid SDN architecture has to be considered , as it is the feasible solution to change to SDN

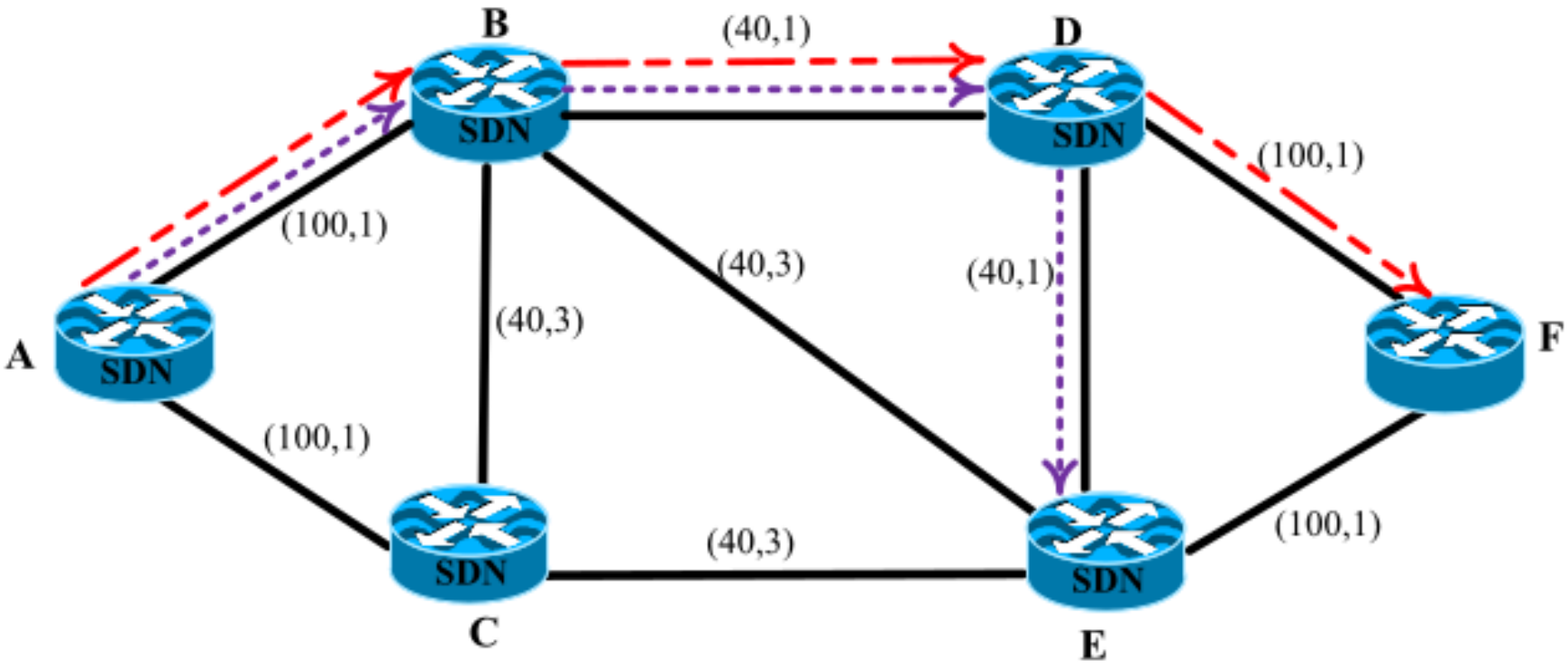
Procedure

In SDN networks, TMM uses the flow rules to pick flows for direct measurement, and TE uses flow rules to adjust the flow paths.

- Formulation of TMM and TE as joint optimization problem
- Algorithm to provide direct measurements for the initial TM estimation.
- Methods named TMM First (TMMF) and TE First (TEF) to design flow rules for TMM and TE tasks.
- Evaluation of performance of TMMF and TEF.
- Periodically (or whentraffic pattern change) the network controller will call the optimization problem which takes the previous estimated TM and adjusts the traffic.

Recent Work and Example

Recent works on TMM and TE show that they are developing the perfor- mance of TMM but they are not considering the TCAM capacity and flow aggre- gation constraints.



(a)

Estimation of Initial traffic matrix

- Before joint optimization, we need a good estimate of the initial TM, for this paper proposes the Maximum Load Rule First (MLRF).
- The basic idea of MLRF is creating a new rule in the SDN switch to reduce the load on the rule with a maximum load to half. The new rule has a priority greater and has a longer IP prefix than the old rule.
- MLRF searches the prefix trie of source IPs using width first strategy.
- MLRF evidently provide good estimation of flows.

The Joint Optimization Algorithm

The following are two heuristic algorithms used to solve the joint optimization problem:

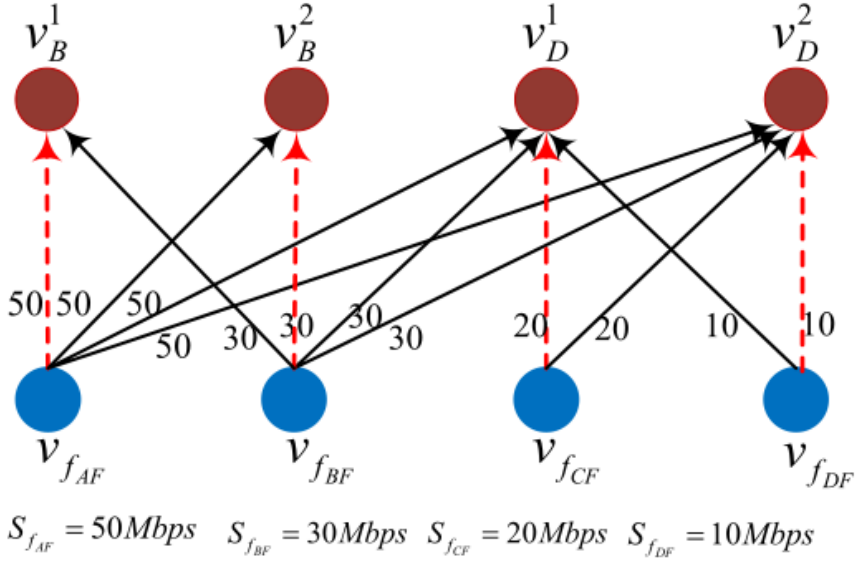
- TMMF
- TEF

TMMF

- The TMMF algorithm first tries to optimize the TMM and then follows TE objectives to adjust the flow rules.
- It is observed that the measurement of sizes of large flows increases the efficiency of TM measurement since they contribute a significant chunk of traffic.
- It is computationally better in comparison with iSTAMP

TMMF

- TMMF uses per-flow sizes based on MLRF which does not have accurate sizes but enough to identify large flows
- Flow Measurement Allocation is to find the node at which a flow will be measured directly (note that all flows need not be measured directly) obeying all the constraints.
- FAM is solved using the maximum matching problem on the bipartite graph formed by the flows and TCAM entries in every node.



TMMF: TE objective

TMMF follows TE objectives to adjust the flows. We assume that all the default routing rules are based on shortest-path routing.

Procedure

- we find a neighbor node of the measurement node, and then we will find whether the path for the flow passing through the measurement node and its neighbor is feasible or not.
- if it is feasible then we add the path to the set of feasible candidate paths for the flow.
- we have to select a path from the set of feasible paths which has a minimum-maximum link utilization(TE objective) and TCAM constraint.
- According to the selected path flow rules are adjusted in the SDN nodes.

TEF

The TEF algorithm first tries to follow TE objectives to adjust the flow rules and then optimizes TMM.

Procedure

- Assumes that all the feasible paths are calculated.
- To reduce time complexity of the optimization problem, it uses a modified k-shortest path algorithm which gives k-feasible paths for each node
- Optimization is costlier in TEF in comparision with TMMF.

TEF: Genetic Algorithm and TMM

- The paper proposes to use a Genetic Algorithm is used to find a path for each node that follows the TE objective from the feasible paths
- the fitness function contains the relation between maximum link utilization and the available TCAM entries.

TMM objective

- The selected path for flow by the genetic algorithm may not be the shortest path.
- The change between the shortest path and the candidate path is at the SDN node.
- The new rules have to be added at the SDN node, which forwards the flow to the next neighbor in the candidate path.
- After this, if there are any remaining TCAM entries, they are used to measure large flow, which was not being directly measured.

Performance Evaluation

- We compare TMMF and TEF with bench-mark algorithms such as iSTAMP+EST and iSTAMP+BAT.
- performance metrics used are
  - Normalised Mean Absolute Error (NMAE) for TM estimation accuracy
  - the average probability of detection(P d HH)
  - false alarm (P f a HH) for performance TMMF and TEF
  - Maximum Link Utilisation(MLU) for TE performance.
- All algorithms perform better as the aggregation ratio increases / SDN switches increases. TMMF has a lower(better) NMAE than that TEF, as TMMF first uses the TCAM entries to measure large flows.
- For MLU, As TEF first uses the TCAM entries to adjust the routes, the performance of TEF is better than TMMF.
- MRE of MLU < 0.04, which proves that TMMF and TEF are satisfactory for implementing TMM and Traffic Engineering objectives.

Critiques

- The proposed system may take more time to solve the optimization problem MILP in the case of large networks. A large network implies more nodes implies more constraints to solve the optimization problem which takes more time to solve, Hence degrading the performance of the system.
- In the paper, there is no mention of how to handle the failures of SDN switches, and controllers. And how the proposed system responds to such failures. like does it crashes the system etc., And also how to handle them in case of transmitting important information.
- The idea of using a Genetic algorithm is impressive in the case of solving the optimization problem instead of MILP, which perfectly solves the problem of time complexity in the case by introducing randomness, even though the Genetic algorithm originally came from a Machine Learning background.

Critiques

- The paper can use already existing computation of the flow rules in nodes. In the case of Traffic matrix estimation, The TM estimation may use the already computed flow rules of the part of the network where the traffic pattern is not changed compared to the whole network instead of estimating the TM of the whole network again, which includes many optimization problems, this problem can be significant in large networks.
- The paper assumes that the feasible paths of the flows are pre-computed in the nodes for the TEF algorithm. As we can see that finding feasible paths for flows is also an optimization problem. So the pre-computation also takes more time because in the TEF algorithm has to find feasible paths for all flows. And the size of the network increases i.e increase in the number of nodes, This pre-computation takes even more time because more constraints are added to the problem

Suggestions

1. In large networks the optimization problem MILP takes more time to solve the problem, Instead of MILP we can use approximate mixed linear integer programming to solve the optimization problem faster which can be helpful in large networks.
2. We could use algorithms like "Russian Roulette" for finding better pairs in the genetic algorithm. We could use heuristic crossovers based on requirements eg: Highly disruptive Heuristic uniform cross-over functions.
3. Usage of ensemble learning methods for DDoS attack detection can be used since the failure of one node could lead to considerable errors in the flow measurements which in turn affect TMM and TE.
4. For the improvement of indirect measurement of flows, we could have communication between the nodes(similar to multi-agent) or we could use the information at one switch, communicate with the controller, and use it for computation at other nodes. if suppose switch A knows the flow fi and it is