Active Probing assisted Monitoring for Software Defined Networks

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Abstract: Efficient and agile control-plane design is crucial for emerging flexible, on-demand optical networks. Active probing assisted monitoring is proposed and shown to reduce monitoring time by around 75% to achieve rapid monitoring in optical networks.
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1. Introduction

OpenFlow has been proposed as a promising technique to provide centralized control for optical networks [1]. This is important for emerging flexible, on-demand optical networks, such as software defined networks and elastic optical networks. The path computation functions introduced, such as impairment aware routing and wavelength assignment, require real time information of the dynamic network status. Optical performance monitoring (OPM) becomes an essential supporting element of the OpenFlow architecture by tracking the characteristics of lightpaths rapidly. OPM also provide various functions such as quality of service monitoring, lightpath setup, impairment compensation and network protection/restoration [2]. In software defined networks, data channels are set up and torn down dynamically. The dynamic nature of transmission impairments requires OPM to be finished in a relatively short time. Many in-service OPM techniques have been proposed to monitor channel impairments during data transmission [3-6]. However, the data channels may only cover part of the network. The time required for data channels to fully cover the whole network may be too long to meet the requirement of dynamic OPM. The OpenFlow can be utilized to set up an extra data channel and inject an active probing signal for monitoring certain uncovered paths proactively [7]. With the assistance of active probing, the required probing time can be greatly reduced and the coverage of performance monitoring can be improved.

In this paper we investigate several active probing schemes that assist the existing in-service monitoring to shorten monitoring time and achieve higher link coverage. In the network, idle transceivers can be utilized for active probing. Simultaneous probing of multiple links can further reduce the probing time. On the other hand, active probing generates additional traffic and may increase blocking probability. The number of simultaneous probing should be limited to avoid jamming the network. The transmission length of each probing signal is assumed to span only one single link for easier setup and impairment estimation.

2. Network model and probing schemes

The performance monitoring process is considered as a Markov Decision Process (MDP) $<S, A, P, R>$ where S is the state of the MDP, A is the actions taken in the MDP, P is the state transition probability matrix and R is the reward function. The state S indicates the monitoring conditions of the whole network, including the set of monitored edges and unmonitored edges. Action A indicates the active probing performed by the probing scheme based on the current state. During active probing, data channels also arrive. The MDP will change to a new state. The state transition probability matrix P depends on the probing scheme used as well as the data channels arrived. The time taken for each state transition period is T. Since the monitoring results of the reconfigurable network status need to be updated repeatedly with a fixed update period, T_{total}, the number of state transitions of the MDP is $m=T_{total}/T$. A smaller T_{total} provides faster monitoring for agile network control. The reward function R is the coverage of the monitored edges of the network, and is defined as the percentage of monitored edges at state S_m after m state transitions. As shown in Fig. 1, consider one of the state transitions, say the n-th transition, from state S_{n-1} to state S_n. Based on the state S_{n-1}, actions are taken by the probing scheme such that extra P_n edges are monitored by active probing during state transition. Note that P_n should not be larger than the maximum number of concurrent probing (a parameter to be set) per state transition. On the other hand, K_n data channels also arrive during this state transition. After the state transition is completed, a new state S_n is reached.

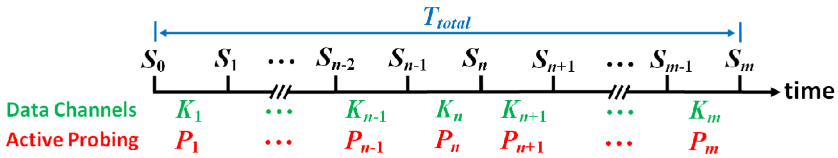

Fig. 1. The update period starts from S_0 and ends at S_m.

The first objective of the performance monitoring schemes is to maximize the *Coverage*, defined as the percentage of edges that have been monitored at the final state S_m for a given amount of total active probing $P_{total}=\sum_{n=1}^{m} P_n$. The second objective is to reduce the *Blocking probability* induced by active probing. In the following we consider two probing approaches aiming at these two objectives respectively. For the first objective, the approach is to arrange as many probing channels as possible during the last state transition, and then the number of probing channels is reduced monotonically for the earlier states transitions. This method is called *increasing probing number* as $P_1 \le P_2 \le \cdots \le P_m$. Note that the data channels arriving during the n-th state transition may traverse some edges that have been covered at state S_{n-1} or earlier. Denote the number of these edges by Q_n. The total number of paths monitored at state S_m is

$$|V_m| = \sum_{n=1}^{m} (K_n - Q_n + P_n). \qquad (1)$$

K_n is the number of data channel arrivals and is uncontrollable by the actions of MDP. This method tries to minimize Q_n so as to minimize the wasting of active probing channels. The second approach, called *constant* arrival, is to assign $P_n = C\text{-}K_{n-1}$(P_n=0 if negative), where C is a constant obtained by $C = \lambda T + P_{total}/m$ and λ is the arrival rate of data channels. C is the estimated number of combined arrivals, including the arrivals of data channels and active probing channels, per state transition. This method intends to average the number of combined arrivals in the network among all state transitions. To further verify these heuristic methods, we investigate the performance with respect to the *average probing* scheme ($P_1=P_2=\ldots=P_m$) via simulations.

Note that the probing sequence of edges (which edge to probe first) also affects the coverage and blocking probability. Consider the shortest paths between all possible source-destination pairs in the network. The percentage that an edge is traversed by these paths is defined as the edge occupancy probability. Thus busy edges have higher edge occupancy probability and the unpopular edges have lower edge occupancy probability. We sort the edges based on edge occupancy probability and investigate three probing sequences: probe unpopular edges first, probe busy edges first and randomly select edges to probe. The combination of heuristic probing approaches and probing sequences generates nine different heuristic probing schemes, as listed in Table 1.

Table 1. The notations of nine combinations of different schemes

Notations	average probing $P_1=P_2=\ldots=P_m$	increasing probing number $P_1 \le P_2 \le \cdots \le P_m$	constant arrivals $P_n = C\text{-}K_{n-1}$
randomly probe edges	AR	IR	CR
probe busy edges first	AB	IB	CB
probe unpopular edges first	AU	IU	CU

3. Simulation Results

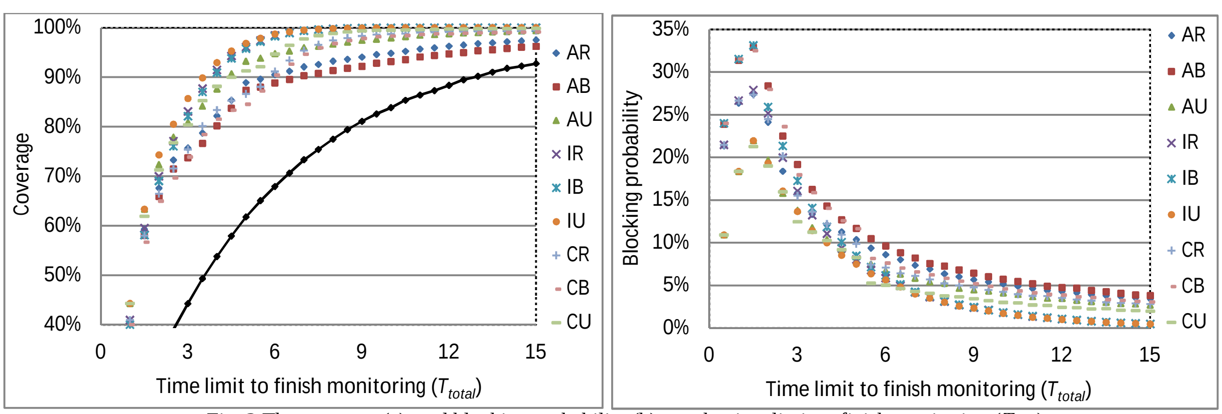

Fig. 2.The coverage (a) and blocking probability (b) vs. the time limit to finish monitoring (T_{total}).

To evaluate the performance of the heuristic probing schemes, simulations on the NSF network are performed. In the simulation the sources and destinations of the data channels in the network are randomly generated, with exponential arrival time and exponential holding time. It is assumed that data channel always traverses the shortest path between source and destination. The performance of different schemes is evaluated by two parameters, coverage and blocking probability. 10000 iterations are established. The following default values for different parameters are set, and some will be varied in the later investigation. T_{total} is equal to five time units in the Matlab simulation. The average waiting time $1/\lambda$ of arrival and departure of data channels is set to be 0.5 time units. The probing time required for establishing an active probing, T, is also set to be 0.5 time units. There are 14 nodes and 20 edges in the NSF network. The total number of active probing channels P_{total} is 10 with a maximum of three concurrent probing channels allowed during each state transition.

Fig. 2 shows the coverage and blocking probability for different T_{total}. The schemes with increasing probing number (IR, IB, IU) outperform other schemes on link coverage, taking only six time units to achieve coverage of 98% of network links compared to 10 time units for average probing (AU). The black curve in Fig. 2(a) is the case that no active probing is established. It takes 24 time units to cover 98% of the total edges. By applying the scheme IU, the time required to cover 98% of network links reduces to six time units, with a reduction of around 75% compared to the case without active probing. Fig. 2(b) depicts that probing unpopular edges first(AU, IU, CU) is better in reducing blocking probability when T_{total} is smaller than 7, whereas the schemes of increasing probing number (IR, IB, IU) is more effective in reducing the blocking probability when T_{total} is larger than 7.

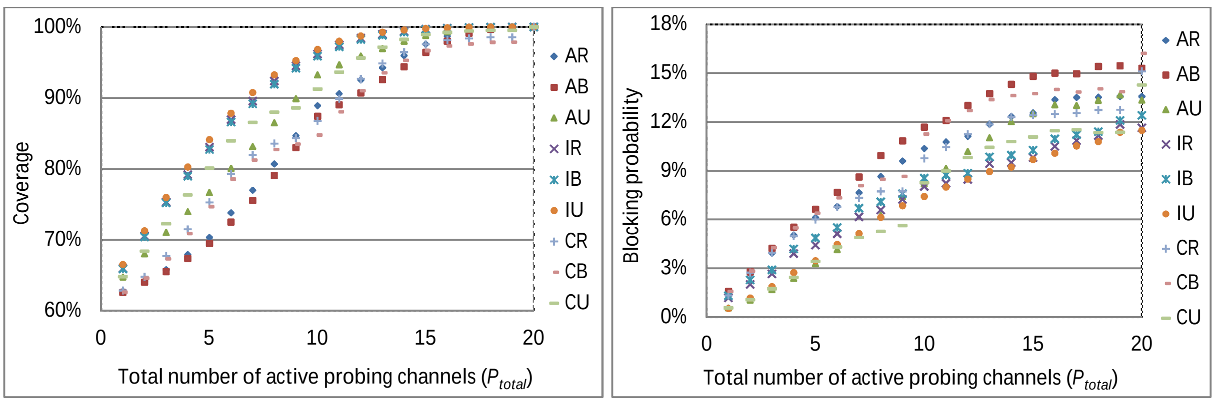

Fig. 3.The coverage (a) and blocking probability (b) vs. the total number of active probing channels(P_{total}).

Fig. 3 shows that adding more active probing channels will increase the coverage as well as the blocking probability, as expected. It takes 12 active probing channels for schemes with increasing probing number (IR, IB, IU) to achieve 98% coverage while average probing (AU) needs 15. On the other hand, probing unpopular edges first (AU, IU, CU) performs better on reducing blocking probability when the number of probing channels is less than 10. When there are more probing channels, the schemes with increasing probing number (IR, IB, IU) is more effective in reducing the blocking probability.

4. Conclusion

We propose and investigate nine different active probing schemes and compare their performance for different update period T_{total} and total number of active probing P_{total}. With the assistance of active probing, the monitoring time can be reduced by around 75% of that without active probing. The simulation results on NSF network show that the probing scheme IU (increase probing number and probe unpopular edge first) achieves the best coverage.

5. References

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