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Network Topology Discovery and Its Applications

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Abstract

The knowledge of network topology is vital for various network management tasks and applications in different types of networks such as routing, flow control, traffic shaping, resource scheduling, performance evaluation and optimization. Network topology discovery (NTD) has thus become a critical research area of increasing significance in both theory and applications. This thesis is devoted to this area, concentrated on the topic of NTD and its applications in the following three aspects covering both wired and wireless networks:

1. TD for multicast network and its applications in performance evaluation.
2. Mobile agent (MA) --- based TD and performance analysis.
3. Topology analysis in wireless sensor network and its applications in routing.

For multicast network, we apply multicast-based network tomography to infer the network topology and internal loss/delay performance. Different from previous work, we propose Binary Loss Tree Classification with Hop count (HBLT) and Binary Hamming distance Classification (BHC) algorithms which take hop count and hamming distance of sequences on receipt/loss of probe packets maintained at each pair of nodes into account respectively. HBLT that considers level information improves greatly in inference efficiency. BHC applies the hamming distance approach for siblings classification and hop count information, by which it achieves a better performance for TD than all previous approaches based on the well-known technique of traditional A-approach in siblings classifications. Based on discovered topology, we study its applications in network-internal loss/delay performance inference. We propose a novel method to infer internal links' loss rates which significantly improves the efficiency of loss performance inference than the previous methods. We also present a hamming distance matrix-based loss/delay performance inference approach by employing end-to-end loss/delay measurements. The accuracy and efficiency of these schemes are proved by detailed theoretical analysis and validated by simulation results.

As a development in new approaches for TD, we apply MA technology in TD and build statistical models to study its performance. We propose several mechanisms for both Internet and multicast network TD, including the report-at-newly-found-nodes (RN) algorithm and report-at-leaf-nodes (RL) algorithm. Through analysis on the behavior of MA with different report fashion, we study the performance of different mechanisms for both Internet and multicast network TD and verify their feasibility in simulated networks. Analytical and simulation results show that, in MA systems, TD can be performed correctly and efficiently due to inherent advantages of MA.

We further extend our research to wireless sensor networks (WSNs) and address coverage, connectivity, reliability and energy-efficiency, which are the most important issues in WSNs, from the topology point of view. We study topology deployment schemes to meet different requirements in coverage and reliability. We further propose two routing schemes to achieve desired energy-efficiency for WSNs with patterned topologies. One protocol incorporates different route selection functions by combining the length of route and the number of streams at individual nodes. This protocol requires only neighboring information and has clear advantages for achieving different performance goals. The second protocol employs the random walk technique and shows performance improvements for small-size data transmission. This protocol achieves high successful transmission rate within a limited number of steps which is quantitatively analyzed for the first time to our knowledge, thus improving in energy-efficiency over other protocols.

Keywords: Algorithm, mobile agent, multicast, performance inference, routing protocol, topology discovery, wireless sensor network.