**CONCLUSION**

Testing liveness of a network is a fundamental problem for ISPs and large data center operators. Sending probes between every pair of edge ports is neither exhaustive nor scalable [30]. It suffices to find a minimal set of end-to-end packets that traverse each link. However, doing this requires a way of abstracting across device specific configuration files (e.g., header space), generating headers and the links they reach (e.g., all-pairs reachability), and finally determining a minimum set of test packets (Min-Set-Cover). Even the fundamental problem of automatically generating test packets for efficient liveness testing requires techniques akin to ATPG.

ATPG, however, goes much further than liveness testing with the same framework. ATPG can test for reachability policy (by testing all rules including drop rules) and performance health (by associating performance measures such as latency and loss with test packets). Our implementation also augments testing with a simple fault localization scheme also constructed using the header space framework. As in software testing, the formal model helps maximize test coverage while minimizing test packets. Our results show that all forwarding rules in Stanford backbone or Internet2 can be exercised by a surprisingly small number of test packets ( for Stanford, and for Internet2).

Network managers today use primitive tools such as and. Our survey results indicate that they are eager for more sophisticated tools. Other fields of engineering indicate that these desires are not unreasonable: For example, both

the ASIC and software design industries are buttressed by billion-dollar tool businesses that supply techniques for both static (e.g., design rule) and dynamic (e.g., timing) verification. In fact, many months after we built and named our system, we discovered to our surprise that ATPG was awell-known acronym in hardware chip testing, where it stands for Automatic Test *Pattern* Generation [2]. We hope network ATPG will be equally useful for automated dynamic testing of production networks.