Towards Cost-Effective Service Provisioning and Survivability in Ultra High Speed Networks

PI: Bin Wang
Wright State University
DoE Collaborators: Drs. Nagi Rao, Bill Wing, Oak Ridge National Lab

Abstract

Future DOE networks are expected to have the ability to dynamically provision on-demand survivable services to suit the needs of various high performance scientific applications and remote collaboration. As the backbone network is moving towards optical networks, the project studies dynamic service provisioning and survivability issues in the context of the generalized MPLS (GMPLS) framework. In this project, an integrated framework to support dynamic service and survivability provisioning in WDM optical networks is proposed, in which effective mechanisms will be developed to address various issues including (1) Dynamic holding-time aware unicast and multicast service provisioning to facilitate large distributed collaborative applications; (2) Traffic classification, quality of service and survivability mapping; (3) Diverse routing with shared risk link group failures; (4) Integrated IP and WDM routing and wavelength assignment; (5) Intelligent survivable tetrabit traffic grooming; and (6) Scalable effective survivability provisioning to enable a spectrum of quality of protection to different applications and, at the same time, to achieve a proper balance between provisioning cost and scalability. Component schemes on scalable flexible dynamic service and survivability provisioning are being developed and evaluated through mathematical analysis, extensive simulation studies, and potential empirical evaluation via implementation and testing in collaboration with the DoE Ultra Science networks. This project will result in significant contributions to the understanding of the fundamental tradeoffs in building/managing ultra-high speed networks with dynamic service and assured survivability provisioning in a scalable and cost effective manner. The project will have a significant impact on education with curricular improvements, the active involvement and training of graduate students in the frontiers of networking research.

Major Research Activities

Unicast and Multicast Service Provisioning under a General Sliding Scheduled Traffic Model We study issues in the context of the MPLS/generalized MPLS (GMPLS) framework. In particular, we propose a general scheduled traffic model, *sliding scheduled traffic model*, since DOE large-scale science applications must deliver throughput at a specific time with certain duration. In this model, the setup time of a demand whose holding-time is not known in advance. Rather the demand is allowed to be provisioned in a pre-specified larger time window. We study the static service provisioning as well as dynamic service provisioning problems for unicast demands and multicast sliding scheduled demands. In the static service provisioning problem, all traffic demands are known in advance, the problem is then a space-time routing and wavelength assignment problem with an optimization objective of minimizing the total resources used. In the dynamic service provisioning case, traffic demands arrive sequentially, a traffic demand needs to be accommodated using a minimal amount of resource upon its arrival. The objective is to minimize the demand blocking probability. We also study the schedulability conditions or performance bounds that can be obtained under the sliding scheduled traffic model.

Survivable Service Provisioning We study resource efficient mechanisms for survivable service provisioning. For holding time unaware traffic demands, we propose and study various shared path based protection schemes for static as well as dynamic traffic demands under the single failure model. We also study pre-configured cycle (*p*-cycle) based protection schemes under

various network configurations, for example, networks with partial wavelength conversion or sparse wavelength conversion, and *p*-cycles can use wavelength conversion. In addition, we study protection schemes to deal with multiple simultaneous failures (e.g., shared risk link group (SRLG) failures). Moreover, we study survivable service provisioning under the scheduled traffic model in wavelength convertible WDM optical mesh networks. We formulate the problem as integer linear programs that maximally exploit network resource reuse in both space and time. The objective is to minimize the total number of wavelength-links used by working paths and protection paths of all traffic demands while 100% restorability is guaranteed against any single failures. The study is extended to the general sliding scheduled traffic model and to deal with multiple simultaneous failures, such as SRLG failures under this traffic model.

Diverse Routing in Networks with SRLGs We study the diverse routing problem in WDM optical networks with SRLG failures. We consider a more general case of SRLG failures than those considered in existing work. All the optical links in an SRLG share a common endpoint. In addition, a link can belong to arbitrary number of SRLG groups and an SRLG may include more than two links. This definition of SRLGs is very general and includes many practical scenarios. We develop a polynomial time optimal algorithm to find a pair of least cost SRLG-disjoint paths between a source and a destination. We prove the correctness of the algorithm which is also shown to be more time efficient than previous algorithms that are based on the graph transformation approach. In addition, we study SRLG-constrained least cost path routing problem that finds a least cost path passing through a bounded number of SRLGs. The goal is to offer an approach to tradeoff the path cost and the SRLG cost during routing.

Traffic Grooming Traffic grooming is an operation to consolidate sub-wavelength client traffic (unicast and/or multicast) onto lightpaths in the interworking of the optical network and client networks. Depending on whether the client traffic is static or dynamic, it can be classified into static and dynamic traffic grooming. We study traffic grooming of static and dynamic scheduled traffic demands. In addition, we study how to design logical topology for dynamic traffic grooming. We consider two relevant problems: 1) minimize network resource (e.g., wavelengths) usage constrained by given traffic blocking requirements; 2) maximize performance or revenue constrained by given network resource. We formulate them into integer linear programming (ILP) problems. In the formulation, we consider wavelength assignment for lightpaths, and wavelength conversion in the optical network. The formulation is demonstrated to be highly effective for small to medium sized networks. For large networks, we propose heuristic algorithms that can obtain near-optimal performance. Finally, we study grooming of data bursts in optical burst switched networks.

Quality of Protection We study the integration of service provisioning with grade of protection to offer different survivable services to users with diverse protection requirements: no protection, restoration/protection against single, dual, multiple failures.

Impact to DoE Science Application

Results of this project (for example, the static and dynamic scheduling algorithms developed) offer effective approaches to provisioning services in future DOE networks like the UltraNet. The results also provide means for survivable service provisioning and resource efficient service provisioning through various diverse routing algorithms, protection/restoration schemes, and traffic grooming schemes that have been developed or being developed.