CHAPTER 2

LITERATURE REVIEW

A deep literature review has been done in the area of wavelength assignment techniques and in fault tolerance schemes.

2.1 WAVELENGTH ASSIGNMENT IN WDM

Dhritiman Banerjee and Biswanath Mukherjee (1996) proposed the divide and conquer mechanism for solving Routing and Wavelength Assignment problem. A linear programming formulation was used along with good approximation techniques to solve the static RWA problem by-partitioning it into several smaller, manageable sub problems. Simple heuristics were used for the dynamic case; the results obtained in each case were close to an asymptotic lower bound obtained through a LP formulation.

Subramaniam et al (1996) depicted that when the number of wavelengths increases, wavelength converters become more useful since this leads to the mixing of more connections. However, after a certain point, increasing the optical channels with different wavelengths does not produce new conversion benefits.

Rajiv Ramaswami and Kumar Sivarajan (1998) considered the problem of routing connections in a reconfigurable optical network using WDM. Each connection between a pair of nodes in the network is assigned a path through the network and a wavelength on that path, such that connections whose paths share a common link in the network are assigned different wavelengths. An upper bound on the carried traffic of connections
for any RWA algorithm in such a network is derived. This bound, scales with the number of wavelengths is achieved asymptotically by a fixed RWA algorithm. Also a similar bound for optical networks using dynamic wavelength converters are derived, which are equivalent to circuit-switched telephone networks and compared the two cases for different examples. The result shows that it is feasible to provide several optical connections to each node in a large network using a limited number of wavelengths.

Karasan and Ayanoglu (1998) showed that First Fit or Most Used wavelength selection algorithms produce a low conversion gain compared to other algorithms when the shortest path routing algorithm is used.

Redundant trees are used to provide rapid recovery which is presented by Medard et al (1999). Their algorithm constructs two trees in such a fashion that each destination vertex is connected to the source by at least one of the directed trees when any vertex in the graph is eliminated.

Ramu Ramamurthy and Biswanath Mukherjee (2002) presented Integer Linear Program (ILP) formulations for the routing and wavelength assignment problem which are developed for a static traffic demand for both path and link protection schemes.

Qian-Ping Gu and Shietung Peng (2003) studied the key issues in WDM optical network routing and to minimize the number of wavelengths for realizing a routing request. For a fundamental communication pattern and permutation, it is known that the number of wavelengths needed in one-hop routing on the butterfly networks is such that it is far beyond the number of wavelengths available in optical links. In general, the butterfly network is a type of network which implements a scheme that connects the units of a multiprocessing system and needs $n$ no. of stages to connect $2^n$ processors; at each stage a switch is thrown, depending on a particular bit in the addresses of
the processors being connected. The result implies that any permutation can be realized in at most two-hops on the butterfly and its variants of practical size.

Xiangdong Qin and Yuanyuan Yang (2003) surveyed the current switching technologies in wavelength-routed WDM networks. Topics include fundamental principles, fabrication, performances of Optical Cross connects (OXC)s and also analyze the impact of wavelength converters on OXC$s. Different OXC architectures based on the utilization of wavelength conversion are compared and examined in terms of permutation, multicast capabilities and network complexity.

Pin-Han Ho and Hussein Moultah (2003) solved the problem of dynamic Quality-of-Service (QoS) routing and wavelength assignment for multi-service WDM mesh networks with a special focus on the implementation in normal standard networks, such as Metropolitan Area Networks (MAN$s). Also a novel algorithm called Capacity-Balanced Alternative Routing (C-BAR), which deploys alternative paths between each Source - Destination pair, so that the routing of light paths can take the most advantages of the load balancing characteristic of the alternative paths. Based on the results of C-BAR, a novel QoS routing and wavelength assignment algorithm for achieving an efficient inter-class resource management is proposed by this author. The results show that the mechanism of interruption on the best-effort traffic and the adoption of the virtual residual capacity in cost function can achieve a solid improvement on the revenue generated and also reduction in the blocking of QoS traffic.

Deying et al (2003) considered a wavelength assignment problem in multifiber all-optical WDM networks. The problem is, given the number of fibers in a link and the number of wavelengths available on each fiber, assigning the wavelengths to a set of connections such that the system blockings being minimized is a task. The problem is formulated as an Integer
Linear Programming problem and then two heuristic methods are proposed in this paper. One of the heuristic methods is based on Linear Programming relaxation of the integer linear programming and has time-complexity of $O(n^{3.5})$. The other is to apply the primal-dual technique and has time-complexity of $O(n^2)$ where $n$ is $t \times W$ ($t$ is the number of connections and $W$ is the number of wavelengths). The simulation study shows that increasing only a small number of fibers of a link can considerably improve network performance.

Ibrahim Alfouzan and Anura Jayasumana (2003) considered the problem of reconfiguring wavelength routed optical networks when the traffic demands changes. When reconfiguring the wavelength assignment according to the traffic demand, it is important to reduce the number of receivers that need to be returned. Furthermore, after the reconfiguration, the load needs to be balanced among the wavelengths. The tradeoff here is between the number of receivers to be returned and the degree of network load balance. After tracking the traffic demand on real networks to see the effect of the traffic changes on the network load balance, an algorithm has been developed for wavelength reconfiguration. The Most and Least Loaded Channel Balance (MLLCB) algorithm provides very good results in terms of the required number of receivers to be returned and the load balance. Comparison of MLLCB algorithm with GLPT algorithms shows a very significant improvement in performance.

Bo Wen et al (2005) presented the connection-assignment problem for a time-division-multiplexed (TDM) wavelength-routed (WR) optical wavelength-division-multiplexing (WDM) network. The authors improved the channel utilization by deploying TDM (Time Division Multiplexing) in Wavelength routed network. The authors presented a family of RWTA (Routing Wavelength and Time slot Assignment) and studied blocking
performance of shortest path routing algorithm with incorporated link cost function as Least Resistance Weight (LRW). For time slot allocation, the authors introduced LLT (Least Loaded Time slot) algorithm. Simulation were performed to compare the performance of TDM architecture with traditional WR architectures and proved that TDM provides substantial gains, especially for multifibre networks.

Alfouzan and Woodward (2006) considered the problem of reconfiguring broadcast and select single-hop WDM networks to maintain a balanced load when the traffic demand changes. When the load becomes unbalanced, the wavelength assignment has to be reconfigured. When reconfiguring the wavelength assignment according to the new traffic demand, reduce the number of receivers that need to be retuned correspondingly for the reduction of disruption in network operation. Also, two wavelength assignment reconfiguration algorithms namely One-Dimensional Transfer (1DT) and the Two-Directional Transfer (2DT) algorithms are introduced by this author.

Poompat Saengudomlert et al (2006) proposed an on-line routing and wavelength assignment (RWA) algorithms for WDM bidirectional ring and torus networks with N nodes. The algorithms dynamically support all k-allowable traffic matrices, where k denotes an arbitrary integer vector \([k_1, k_2 \ldots k_n]\), and node \(1 \leq i \leq N\) can transmit at most of the wavelengths and receive at most of the wavelengths.

Rajalakshmi et al (2007) considered the problem of enhancing the blocking performance, in the circuit-switched wide-area optical WDM networks with no wavelength conversion at the nodes. The limitation of such a no conversion network is the Wavelength Continuity Constraint (WCC) which requires the same wavelength on all the hops of the path. Whenever there is a session request, a light path has to be established in the network. If
the light path could not be established, light path request rejection or call blocking occurs. Two heuristic algorithms namely Minimum Overlap wavelength to Least Congested wavelength (MOLC) and Random Reassignment are proposed in this paper. When the new call gets blocked due to WCC, the already established calls or light paths are wavelength reassigned, so as to create a wavelength-continuous route in order to accommodate the new call. During wavelength reassignment, the routes for all the calls remain the same, i.e. no rerouting is done. Reassignment algorithm can mostly remove the blocking due to the WCC and can achieve the wavelength conversion performance.

Der-Rong Din (2007) considered the routing and wavelength assignment problem for anycast (ARWA) in wavelength division multiplexed networks. A hybrid method, which combines simulated annealing and genetic algorithm techniques, was proposed to solve the ARWA problem.

I-Shyan Hwang et al (2008) proposed a fault-tolerant architecture to provide overall protection in WDM –Ethernet Passive Optical Network (WDM-EPON) and in Cost-based Fault-tolerant WDM-EPON (CFT-WDM-EPON). Additionally, a Prediction-based Fair Wavelength and Bandwidth Allocation (PFWBA) scheme is also proposed to enhance the differentiated services for WDM-EPON based on the Dynamic Wavelength Allocation (DWA) and Prediction-based Fair Excessive Bandwidth Reallocation (PFEBR). The PFWBA scheme integrates an efficient dynamic wavelength allocation and Early Dynamic Bandwidth Allocation (E-DBA) mechanism of the PFEBR to improve the prediction accuracy and system performance.

James et al (2009) proposed a measurement based on the Lagrangian relaxation framework. Such a quantitative measurement can be naturally acquired along with the optimization process to obtain the optimal solution to the static routing and wavelength assignment problem. Also three
practical applications of the critical resource analysis in WDM network planning are investigated. The first application, uses proposed measurement to identify critical resources to decide the best way to add or reallocate resources. In the second application, the impact of the addition or removal of light path demands on the design objective which is estimated. This kind of estimation helps to set a proper price for light path demands. In the third application, the results of the critical resource analysis are used to speed up the convergence of the optimization process for different network scenarios.

Manoj Kumar Dutta and Chaubey (2009) proposed a model for priority assignment to the incoming call connection request for all-optical WDM communication, adopting standard queuing theory concept. The model has been proposed for three different levels of call connection priorities, categorizing them into three types of signals as type0, type1 and type2 according to priority, and generation probabilities of P0, P1 and P2 respectively. The traffic at the node will be serviced according to the priority leveled on the header of the assigned packets

Simone Cintra Chagas et al (2009) proposed a distributed on-demand routing and wavelength assignment algorithm for WDM networks namely Distributed Light-path Allocation (DLA). It is capable to select routes and establish light paths via exchange of message without imposing a major overhead on the network. The scheme can balance the load in a WDM network. The proposed solution is adaptable and can be easily implemented and incorporated in a WDM network.

Fen Zhou et al (2009) proposed the multicast routing and wavelength assignment for WDM mesh network with sparse splitting. The algorithm tries to minimize the session blocking probability or minimize the number of wavelengths needed per fiber link. To route the multicast sessions, alternative routing method is employed, which pre-computes a set of light-
forests for each session. And the wavelength assignment for the light forests is translated into a coloring problem by constructing an auxiliary conflict graph. By merging the two steps, the multicast routing and wavelength assignment problem can be solved.

Sangeetha et al (2009) presented the performance analysis on wavelength assignment problem in optical WDM networks. The authors compared the blocking probability of random wavelength assignment algorithm with the first-fit wavelength assignment algorithm. In addition to that, sparse wavelength conversion case was compared with no wavelength conversion and full wavelength conversion cases. All these comparisons were done on the basis of blocking probability under constant number of links, constant numbers of channels but varying the load per link (in Erlangs). The blocking probability in case of random algorithm is always greater than first-fit wavelength assignment algorithm. The blocking probability is minimum in case of wavelength conversion, whereas in case of no conversion, the first-fit algorithm has better results as compared to that of random wavelength assignment algorithm.

Virendra Singh Shekhawat et al (2010) proposed a weight based Edge Disjoint Path (EDP) algorithm for RWA to optimize the wavelength resources in a wavelength routed WDM networks. The objective is to minimize the number of wavelengths for a given set of request. Here dynamic weight is assigned on the base of the number of wavelengths which are currently being used on the edge. More the number of wavelengths are used in an edge at a time; more the weight will be assigned to it and it is less likely to be used that edge for light path establishment for a new request. A path is searched by first choosing with minimum dynamic weight and then with minimum static weight from the available EDPs for a given pair of source and destination node.
Kiyo Ishii et al (2010) proposed a wavelength assignment algorithm that offers full-mesh node connectivity of two concatenated, bidirectional ring networks. This algorithm minimizes the number of wavelengths. Three schemes that can reduce the switch scale at the ring-concatenating nodes: separation of intra-ring and inter-ring operation, hierarchical optical path switching, and introduction of efficient protection switching have been described. The proposed node architectures applying the described schemes in combined manner namely category one to category four which reduce the optical switch size by 50% to 75% compared with the conventional arrangement is clarified.

Paulo Henrique Gonçalves Bezerra et al (2010) presented three algorithms for allocating wavelength optical networks WDM (Wavelength Division Multiplexing) and they are: first-fit, least-used and most-used. The objective of the experiment was to simulate the performance of allocation algorithms on relevant aspects: throughput and blocking probability. To this end, a series of measurements were performed using a simulation tool for networks WDM called OWNS (Optical WDM Network Simulator) to perform an analysis of the problem RWA (Routing and Wavelength Assignment) based on the algorithms studied in this article. The results of the experiments back in a different analysis where the allocation of wavelengths where overlaps in importance to routing.
2.2 FAULT TOLERANCE IN WDM

Ho and Mouftah (2001) proposed the technique called Short Leap Shared Protection (SLSP) which implements scalable end-to-end guaranteed service protection. The concept of SLSP is to divide the protected working path into several overlapped segments which are assigned by first hop node. The segments are identified as PID (Protection domain ID) which is used for calculation of protection path. The presence of overlapped protection domain with neighboring sub-domains by a link, implements the path recovery whenever failure occurs.

A new multiplexing technique called primary-backup multiplexing is proposed by Mohan et al (2001) to improve resource utilization. This technique allows a primary light path to share the same wavelength with some backup light path.

Muriel Medard and Steven Lumetta (2001) described the protection routes that are pre-computed at a single location and thus it is centralized. Before the restoration of the traffic, some distributed reconfiguration of optical switches is essential. On the other hand, restoration techniques depend upon distributed signaling between nodes or on the allocation of a new path by a central manager.

Sen et al (2001) proposed to use the link-disjoint path pair, whose longer path is the shortest among all such pairs of paths, for path protection so that the delay on the backup path is minimized. The problem of finding such a pair of paths is NP-complete, and uses the one-step approach as the approximation solution.

Hui Zang and Biswanath Mukherjee (2001) developed an on-line network control mechanism to manage the connections in WDM mesh
networks using path protection schemes. A two-step approach to route the connections is used.

Anand et al (2002) described the performance of sub-path protection scheme in terms of capacity utilization and recovery time, compared with path and link protection schemes.

In the study of survivable routing, Eytan Modiano and Narula-Tam (2002) dealt with the problem of routing light paths, so that the virtual topology remains connected when there is a single fiber cut. The problem is formulated as an Integer Linear Program (ILP) and solved for regular topologies and ring topologies.

Su and Sasaki (2003) investigated the relationship between wavelength efficiency and time flexibility of the scheduled demands. A number of heuristics for resource allocation in fault-free networks is presented. The heuristic approaches can be used for large problems and demonstrate that connection holding time aware schemes can achieve much better resource utilization when compared to other such schemes.

Xin et al (2003) attempted to optimize the network resource utilization of each call by minimizing the overall cost of the primary and backup path. The paths are selected from K pre-computed candidate route pairs.

Canhui Ou et al (2004) investigated survivable light path provisioning and fast protection switching for generic mesh-based optical networks employing WDM. A sub path protection is proposed, which is a generalization of shared-path protection. The main ideas of sub path protection are to partition a large optical network into smaller domains and to apply shared-path protection to the optical network such that an intra domain
light path does not use resources of other domains. The primary/backup paths of an inter domain light path exit a domain through a common domain-border node. The RWA problem under sub path protection for a given set of light path requests is mathematically formulated and proved that the problem is NP-complete and developed a heuristic approach to find efficient solutions. Comparisons between sub path protection and shared-path protection on a nationwide network with dozens of wavelengths per fiber are shown for a modest sacrifice in resource utilization. The sub path protection achieves improved survivability, much higher scalability, and significantly reduced fault-recovery time.

Guido Maier et al (2004) investigated the issue of dynamic connections in WDM networks. It is also loaded with the high-priority protected static connections. Various routing strategies have been compared by discrete event simulation in terms of blocking probability. Based on the occupancy cost function, a heuristic algorithm was proposed which takes several possible causes of blocking into account. The behavior of their algorithm was tested in a well known case study of mesh networks, with and without wavelength conversion.

Lu Ruan et al (2004) presented a distributed dynamic routing algorithm for restorable connections that uses load balancing heuristics in both primary and backup path computations to achieve low demand blocking. The key idea was to assign costs to links, so that heavily loaded links will be avoided in the routing of the primary and backup paths and links with a high chance of including a sharable backup channel will be included in the backup path.

Yufeng Xin et al (2004) studied the important fault management issue which concentrates on the fast restoration mechanisms for Optical Burst Switched (OBS) networks. The OBS network operates under the JIT signaling
protocol. The basic routing mechanism is similar to the IP networks, where every OBS node maintains a local forwarding table. The entries in the forwarding table consist of the next hop information for the bursts per destination and per FEC (Forward Equivalent Class). Based on look up the next-hop information in their forwarding tables, OBS nodes forward the incoming burst control packets and set up the connections. The connection set up process is signified by the burst forwarding or burst routing.

Madhyastha et al (2005) addressed the multicast traffic grooming problem in metropolitan WDM ring networks with the objective of minimizing electronic copying. The authors presented an ILP formulation and then developed a heuristic approach that consists of three phases: routing, circle construction and grouping of circles.

Wang et al (2005) provided a heuristic algorithm for scheduling the demands and solving the RWA problem for a fault-free network, without wavelength conversion.

Michael Frederick and Arun Somani (2006) presented a L+1 fault tolerance scheme which is used for the recovery of optical networks from single link failures without the allocation of valuable system resources. While the approach in its simplest form performs well against the existing schemes, the flexibility of L+1 leave many options to examine possible ways to further increase performance.

Mahesh Sivakumar and Krishna Moorthy Sivalingam (2006) presented hybrid failure mechanism to use resources to handle link failures. The authors tried to minimize the spare capacity essential to provide complete survivability. They presented algorithms to achieve high restoration speed and guarantees while optimizing the spare capacity requirements. In addition to that, the authors presented a segment based restoration approach that relaxed
the need to have the same wavelength in the backup paths by better utilizing
the wavelength converters

Wojtek et al (2006) studied the different options for the
survivability implementation in Multi Protocol Label Switching (MPLS) over
Optical Transport Networks (OTNs) in terms of network resource usage and
configuration cost. Two approaches to the survivability deployment were
investigated: single layer survivability, where some recovery mechanism is
implemented in a single network layer and multilayer survivability, where
recovery is implemented in multiple network layers. The survivable MPLS
over OTN design is implemented as a static network optimization problem
and incorporates various methods for spare capacity allocation to reroute
disrupted traffic. For multilayer survivability can achieve up to 22 % savings
in the total configuration cost and up to 37 % in the optical layer cost.

Lei Guo (2007) studied the problem of multiple failures in WDM
networks. In order to improve the survivable performance, he proposed a
heuristic algorithm called Shared Multi-sub backup paths Reprovisioning
(SMR). The survivable performance of SMR in multiple failures was
considerably improved when compared with the previous algorithm.

Rajkumar and Murthy Sharma (2008) proposed a distributed
priority based routing algorithm. In order to establish the primary and backup
light paths, a variety of traffic classes which uses the concept of load
balancing is proposed. Based on the load on the links, their algorithm
estimates the cost metric. The routing of high priority traffic was performed
over the lightly loaded links. Therefore while routing the primary and backup
paths, the lightly loaded links are chosen instead of choosing the links with
heavier loads. The load balancing will not reflect the dynamic load changes
because it is used in the routing metric.
Srinivasan Ramasubramanian (2008) developed a framework to support multiple protection strategies in optical networks, which is in general applicable to any connection-oriented network. The capacity available on a link for routing primary and backup connections is computed depending on the protection strategy. A model for computing service outage and failure recovery times is developed for a connection where notifications of failure location are broadcast in the network. The effectiveness of employing multiple protection strategies is established by studying the performance of three networks for traffic with four types of protection requirement.

Shilpi Garg and Shubham Agrawal (2008) presented a countered expected wavelength and available wavelength algorithm (CTEW). The proposed algorithm first calculates a weight $W$ using a weight function and is applied into Dijkstra's shortest path algorithm. Dijkstra's algorithm will select an optimal path that is lightly loaded with least weight and with a good number of available wavelengths. The maximum number of request served is equal to the total number of available channels in the selected light path.

Yu Dong and Jian Wang (2008) presented an enhanced fault tolerance in large-scale optical switches through innovations in architecture and control logic design. A large-scale switch is constructed from a network of $2 \times 2$ optical Switch Elements (SEs). Classic switch network architectures, such as the Benes, are not designed with fault tolerance in mind. There are three major contributions in the work: (1) an analytical method, referred to as the probability accumulation method, to calculate the average connection blocking probability in a faulty switch network; (2) a failure-aware routing algorithm to effectively circumvent connections from defected SEs in a dilated Benes switch; and (3) the connectivity pattern of the Benes network to further reduce the blocking probability, especially when the SE failure rate is low.
Hongbin Luo et al (2009) considered the problem of routing connections with differentiated reliability in wavelength-division multiplexing mesh networks when backup sharing is not allowed. The objective is to route connections with minimum network cost while meeting their required reliability. It is assumed that the connections are made dynamically one-at-a-time and a decision as to accept or reject a connection has to be made without a priori knowledge of future arrivals. The goal is to achieve efficiency by improved path selection.

By introducing intelligent control, agile all-optical networks can serve dynamic and flexible bandwidth on demand. A protection scheme for single-duct ring networks is proposed by Wei Yang et al (2009) followed by a rearrangeable bandwidth allocation scheme to decrease blocking in critical connection setup. The survivable dual-duct ring infrastructure proposed will have survivability for the type of network in order to improve the efficiency of network resource utilization and signal quality.

Lei Song and Biswanath Mukherjee (2009) presented a novel restoration scheme by jointly considering accumulated downtime and Service Level Agreement (SLA) requirements of faulty connections in order to improve different service availabilities and to achieve high resource efficiency. When a link failure occurs, two sets of faulty connections are examined: (a) connections whose primary or restoration path is disrupted by the failure and (b) connections that are in the “down” state due to some previous failures. An affected connection is switched to its pre-computed or an alternate restoration path if necessary, when its accumulated downtime plus the link repair time will exceed its SLA requirement. The scheme provides differentiated restoration to the existing connections upon a link failure in order to satisfy the connection availability requirements. Also an upgraded version of the scheme that incorporates both excess capacity and
resource preemption into the scheme is proposed. Otherwise, when protection switching of a high-SLA connection fails due to limited bandwidth on some links, it preempts restoration capacity on each link from a low-SLA connection if both disrupted connections share the same restoration capacity and the availability requirement of the low-SLA connection is not violated. The results demonstrated that the algorithm achieves a high availability satisfaction rate and good resource utilization, as well as greatly reduces protection-switching overhead.

Rabindra Ghimire et al (2009) investigated the problem of autonomous multilayer recovery in optical backbone networks. Such recovery had only been sequential in the sense that the published work recovers first in the optical domain, assuming the availability of redundant resources, and then proceeds to recover packet label switched paths. Recovery procedure for recovering packet label switch paths and lambda label switch paths concurrently is reported. Moreover OPNET-based simulation study was conducted that compared the performance of the concurrent scheme with the previously published sequential two-layer recovery scheme. The study showed that the concurrent two-layer recovery scheme performs as much as 44% faster than the sequential two-layer recovery scheme.

Joon Young Kim et al (2009) proposed and demonstrated a simple WDM-PON architecture that provides protection for both the feeder fiber and distribution fiber with a minimum addition of losses in the transmission path. In order to provide the protection function, 1 x 2 optical switches or Ethernet switches at each ONU and OLT is used. In addition, the fault localization is implemented by using a tunable optical time domain reflectometer (OTDR) realized by a Fabry-Perot laser diode (F-P LD) and a tunable filter.

Ramesh and Vaya (2010) presented an adaptive reliable multipath routing (ARMR) protocol. In this protocol, a small fraction of probe packets
are sent by the source along all the paths. By the monitored results from the probe packets on each path, the source estimates the blocking probability. By simulation results, the ARMR protocol concludes low blocking probability and delay with high bandwidth utilization.

Bin Wang and Tianjian Li (2010) studied survivable service provisioning with shared protection under a scheduled traffic model in wavelength convertible WDM optical mesh networks. In the proposed model, a set of demands is given and the setup time and teardown time of a demand are known in advance. Based on different protection schemes used, the problem has been formulated as integer linear programs with different optimization objectives and constraints in the previous work. The objective of the model is to minimize the total network resources used by working paths and protection paths of a given set of demands while 100% restorability is guaranteed against any single failure. The proposed algorithm was evaluated against solutions obtained by integer linear programming.

2.3 FAULT DETECTION AND LOCALIZATION IN WDM

Chung-Sheng Li and Rajiv Ramaswami (1997) presented fault surveillance and fault identification mechanisms for a transparent optical network in which data travels optically from the source node to the destination node without going through any optical-to-electrical (O/E) or electrical-to-optical (E/O) conversion. Mechanisms and algorithms are proposed to detect and isolate faults such as fiber cuts, laser, receiver, or router failures. These mechanisms allow nonintrusive device monitoring without requiring any prior knowledge of the actual protocols being used in the data transmission.

Carmen Mas and Patrick Thiran (2000) proposed an algorithm for locating multiple failures at the physical layer of a WDM network. The
authors identified two different failures such as hard failures and soft failures. Hard failures are detected at the WDM layer whereas soft failures can be detected at the optical layer if proper testing equipment is deployed, but often require performance monitoring at a higher layer (SDH, ATM, or IP). Both types of failures, and both types of error monitoring, are incorporated in their algorithm, which is based on a classification and abstraction of the components of the optical layer and of the upper layer. The proposed scheme handles missing and false alarms. The nonpolynomial computational complexity of the problem is pushed ahead into a precomputational phase, which is done off-line, when the optical channels are set up or cleared down. This results in fast on-line location of the failing components upon reception of the ringing alarms.

Hongsik Choi et al (2002) considered the network survivability which is a critical requirement in the high-speed optical networks. A failure model is considered so that any two links in the network may fail in random order. They have presented three loop back methods of recovering from double-link failures. Only the first two methods require the identification of the failed links. But pre-computing the backup paths for the third method is more complex than the first two methods. The double link failures are tolerated by the heuristic algorithm which pre-computes the backup paths for links.

Jian Wang et al (2002) considered the fault-monitoring functions which are usually provided by the optical-transmission systems. In order to measure the bit error rate in the wavelength channels using SONET framing, the B1 bit in the SONET overhead can be used. Moreover, to detect certain failures like fiber cut in other formatted optical channels, the optical power loss can be used. Optical-Electrical-Optical (OEO) conversion is used before
each OXC port because most of the OXCs use electronic switching fabric. Therefore, faults can be detected on link-by-link basis. Both the end nodes of the failed link can detect the fiber cut for all-optical switches.

Dong-won Shin et al (2004) Proposed an alternative approach by introducing link failure probabilities to the routing problem, and allowing each link to be used for several channels. Based on these assumptions, a survivable multipath routing problem for point to point communication was formulated. Two heuristics schemes, SPMR (Successive Penalization Multipath Routing) and CPMR (Conditional Penalization Multipath Routing) were proposed based on link failures to identify probability to account for the vulnerability of links instead of assuming that maximum number of link failures is known beforehand. The proposed scheme allows link sharing and implements increased routing success rates compared with schemes without link sharing.

Sava Stanic et al (2004) presented the problem of optimal monitor placement in optical networks. The authors first described the types of optical monitoring equipment that are available, and the types of alarms that are generated by these equipments as well as by monitors within typical optical networking components. They have also presented performance results through a mixed integer-linear program (MILP) formulation of the problem, which resulted in significant reductions in the number of monitors required.

Hongqing Zeng and Changcheng Huang (2004) proposed a mechanism for fault detection and path performance monitoring based on decomposing AONs into monitoring cycles. The authors developed two monitoring cycle finding algorithms which are heuristic depth first searching (HDFS) and shortest path Eulerian matching (SPEM). The HDFS and SPEM algorithms are developed for finding monitoring cycles in AONs. The two
algorithms are compared with respect to the maximum and average number of wavelengths occupied by monitoring in nodes and links. Thus the proposed mechanism based on monitoring cycles is a promising fault detection method for AONs. It is also applicable to path transmission performance monitoring. The results also suggest that the SPEM algorithm is better than the HDFS algorithm in terms of the wavelength overhead.

Tao Wu and Arun K. Somani (2005) developed models of crosstalk attack and monitoring node scheme. The attack monitors can collect the information from connections and nodes for diagnostic purpose. However, to detect attack sources, it is not necessary to put monitors at all nodes. Since those connections affected by the attack connection would provide valuable information for diagnosis. Hence, the authors placed relatively small number of monitors on a selected set of nodes in a network which is sufficient to achieve the required level of performance. The authors developed scalable diagnosis scheme which can localize the attack connection efficiently with sparse monitor nodes in the network. The models proposed by these authors can support only cross talk attack and other types of attack cannot be detected.

Jin Cao et al (2005) proposed a Segment Shared Protection Algorithm (SSPA), which is based on the reliability of the networks and the different levels of the fault tolerance requested by the users, to protect the single-link failure in WDM optical networks. The main idea of the SSPA is to provide a backup path for a segment, which is divided in accordance with the policy of the Differentiated Reliability (DiR), on the primary path of each connection request. Under the guarantee of the blocking probability and the connection’s reliability, the SSPA has higher resource utilization ratio and faster recovery time than the previous algorithm PSPA-DiR (Path Shared Protection Algorithm with DiR).
Hongqing Zeng et al (2005) described and analyzed an end-to-end light path fault detection scheme in data plane with the fault notification in control plane. Their effort is mainly focused on reducing the fault detection time. Their performance evaluation shows that their protocol can achieve fast fault detection, and at the same time, the overhead brought to the user data by hello packets is negligible.

Lim et al (2005) presented a simple and cost-effective technique to detect and localize the fiber failures in WDM PON (WDM Passive Optical Network). The proposed technique detected the fiber failures by monitoring the status of the upstream signals and localized these failures in either feeder fiber or drop fibers by reusing the corresponding downstream light sources for the transmission of (Optical Time-Domain Reflectometer) OTDR pulses. The dynamic range of the proposed technique was dependent only on the peak power of the OTDR pulse and not sensitive to the noise characteristics of the light source. The proposed technique could detect and localize the fiber failure in a drop fiber without degrading the performances of other operating channels.

Yonggang Wen et al (2005) proposed a family of failure localization algorithms that exploit the unique properties of all-optical networks. Optical probe signals are sequentially sent along a set of designed light paths and the network state is inferred from the result of this set of end-to-end measurements. The design objective is to minimize the diagnosis effort (e.g., the average number of probes) to locate failures. Using the rich set of results from coding theory to solve the fault diagnosis problem, the authors proved that ‘2m-splitting’ probing scheme is optimum for the special case of single failure over a linear network. Analytical and numerical results suggest that the average number of probes per edge for the run-length probing scheme
is uniformly bounded above by $(1+\varepsilon)H_b(p)$, and converges to the entropy lower bound as the failure probability decreases.

Lu Ruan et al (2006) proposed a dynamic restorable connection establishment scheme that uses p-cycles to protect connections on the working light path. For a given connection request, the proposed scheme first computes a working light path and then computes a set of p-cycles to protect the links on the working light path so that the connection can survive any single link failure. The advantage of the proposed scheme is that it enables fast failure recovery while requiring very simple online computation within the connection establishment time.

Bin Wu et al (2008) considered an optical layer monitoring scheme for fast link failure localization in WDM mesh networks. A new concept for monitoring trail (m-trail) which differs from the existing monitoring cycle (m-cycle) concept by removing the cycle constraint was also proposed. Their numerical result shows that the m-trail based scheme significantly outperforms its m-cycle based counterpart.

Pal et al (2008) proposed fault detection and localization scheme to handle multiple failures in the optical network using WDM technology. This proposed scheme is two-phased scheme containing (i) the detection of faults through monitoring devices raising alarms (fault detection) and (ii) subsequently the localization of these faults (fault localization) by invoking an algorithm. The later phase will obtain a set of potential faulty nodes (links).

Carolina Pinart (2009) proposed the scheme of Bottom-up fault detection and localization, cross-layer information feedback, and hierarchical fault management, together in a common framework. When a failure occurs, it is detected at all the layers that are embedded with detection and/or
monitoring capabilities. The considerations framed by the author (i) Keep fault detection as close to the source of the faults as possible (ii) Use the optical layer for optical-multiplex-related operations. (iii) Apply hierarchical fault detection (iv) Ask for upper-layer feedback (v) Combine path- and link-based detection.

Mazen Khair et al (2009) studied the optimization problems in applying the Limited-perimeter Vector Matching (LVM) protocol for localizing single-link failures in all-optical networks. The authors considered two optimization problems: one is to optimize the traffic distribution so that the fault-localization probability in terms of the number of localized links is maximized, and the other is to optimize the traffic distribution so that the time for localizing a failed link is minimized. They formulated two problems into an ILP problem, and use the CPLEX optimization tool to solve the formulated problems. Their algorithms result in optimizing the traffic distribution, fault-localization probability and minimizing the fault-localization time.