MINIMAL PATH COST-BASED SURVIVABILITY MODEL FOR IP-OVER WDM NETWORKS USING ACO-MST METHODS

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***Abstract*—*Nowadays, the preservation of the survivability of the network devices against the multiple link failures is an attractive research in the Internet Protocol (IP) over Wavelength Division Multiplexing (WDM) networks. Several protection schemes such as the restoration/backup schemes, cross-layer cut sets and shared risk group are used to preserve the network survivability. But, the conversion process of Optical-Electrical-Optical (OEO) conversion among the devices, large processing overhead, lack of instant update of link parameters and the periodical maintenance are the major limitations in such schemes. This paper proposes the full-fledged optical concept with the hybrid algorithms such as Ant Colony Optimization (ACO) and Minimum Spanning Tree (MST) for an efficient communication through the optical links. The proposed research employs the structural approach called Graph theory to model the links and devices as edges and nodes. The delay based pheromone construction and the transition probability estimation in this paper reduces the time consumption for route prediction and the converged quickly. The maintenance of list containing recomputed edge-disjoint alternate paths facilitates the alternate successful light path selection during the failure conditions effectively. The backup path estimation and their storage in the table by using the ACO and MST approaches in this paper predicts the alternate path to avoid the disruption in data transmission during the occurrence of link failures. The broadcast of Link State Advertisement (LSA) messages to the controller from the nodes available in the network provides the break-free data transmission. Based on the status of LSA, the proposed work computes the primary and backup paths for dynamic loading conditions and changes in bandwidth. The comparative analysis of the proposed work with the existing methods regarding the parameters of packet end-to-end delay, burst end-to-end delay, failure path selection ratio and the number of burst send assure the effectiveness of proposed work in IP-over-WDM network.*

Keywords*—*Ant Colony Optimization (ACO), Graph theory, IP over WDM, Link failure, Network Survivability, Optical Burst Switching.

I. INTRODUCTION

Network survivability against the multiple failures such as link and power outage is an attractive research area in cloud computing recently. Failures raised in the interface between the cloud datacenters and the Virtual Machines (VM) decrease the computational and communicational abilities of the cloud that leads to a development of the survivable design. Several approaches(1) are employed to assure the virtual datacenter survivability in different layers. The protection of Internet Protocol (IP) traffic over the optical links is one of the approaches since they play the role of links during the communication. The 1: N protection and the virtual network mapping are some of the optical link protection schemes. The link failure analysis is categorized into two such as single link and multiple link scenarios. The major categories of the single link scenario are disjoint path-based and cross layer cut sets and the divisions of multiple link scenario are Shared Risk Link Group (SRLG) and the restoration/backup schemes. The guarantee of survivability and the protection of spanning tree are the major benefits of single link scenario. The easy recovery of failures in SRLG and the grouping of links through the same fiber are the merits of multiple-link scenario.

The declaration of sufficient conditions for the survivability and the mapping of cloud network with the multiple link failure are the major issues in the IP traffic over the optical links.

With an increase of count value of end-users, the traffic handling by the communication network is huge that leads to the network capacity maximization and energy consumption. The evolution of optical networks acted as the major role in the formation and support of network according to the future needs. The comparison between the

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single-layer green optical networks with the IP over Wavelength Division Multiplexing (WDM)(2)shows that the high-energy consumption is observed in the IP-WDM routers. The dynamic changing traffic scheme introduced in the research handles the peak-hour traffic with the additional resource provisioning ability. Integer Linear Programming (ILP) and the traffic grooming designs based on the light path reduce the energy consumption effectively. But, the higher port cost and the merging of low-wavebands are the major limitations of such ILP models. The recovery from the failure links also the other issue in the ILP models that lead to protection mechanisms.

The hide of failure and the protection of relevant connections (based on the priority level) through restoring facilitates the failure links recovery effectively. Instead of the optical layer recovery, the IP layer recovery by traffic reconfiguring process meet the Quality of Service (QoS) requirements(3). The argument regarding the high-recovery time suggests the researchers re-compute the routing table entries for the avoidance of packet drop. Due to the dynamic (time-varying) nature of traffic and load conditions(4), the virtual topology undergone the reconfiguring process to satisfy the traffic engineering goals and the maximization of network utilization level. With respect to the dynamic load conditions, the resource operators find the IP layer configuration through link weight adjustment and the QoS routing. This type of reconfiguration is not suitable to accommodate the changes in the network states. The reconfiguration progress includes the three major processes such as creation of new IP links, deleting the existing links and both deleting and creation simultaneously. The network operation is made as energy efficient only if the new creating topology replaces the existing one (reconfiguration).

In response to the drastic increase of bandwidth requirements of the internet users, the WDM is considered as an important transmission technique in IP over optical networks. The capacity of the wavelength channel is decided to handle the multiple packet flows. The wavelength channel utilization to meet the high demand flow connection requests is governed by the new technique called traffic grooming(5). It performs the sharing of packet flows into the channel which has the common wavelength. The important aspect of the traffic grooming technique in common wavelength channel is the solution to the green optical network that reduces the number of paths followed by the lights with respect to the networking devices. But, the processing overhead is large in traffic grooming that leads to the unnecessary delay and energy consumption indirectly. The conversion process of optical to electrical and electrical to optical leads to delay in the light path between the source and destination. Hence, the pure optical network concept is the major requirement for network survivability. The technical contributions of proposed work listed as follows:

- An employment of pure optical concept without any electronic conversion reduces the delay in data transmission
- Software Defined Network (SDN) utilization identifies the physical impairments (state of the system) periodically and isolates the data and control plane to avoid the link failures
- The periodical maintenance of connectivity through the Minimum Spanning Tree (MST) and the adaptive Ant Colony Optimization (ACO) even if the number of links are reduced assures the survivability of the network.

The paper is organized as follows: The detailed description about the related works on IP over WDM is presented in section II. The implementation process of proposed hybrid ant colony optimization and the minimum spanning tree approach to assure the survivability against the link failures in section III. The performance of proposed methodology is investigated against the existing algorithms with the parameters in section IV. Finally, the conclusions about the application of proposed work on communication activities presented in section V.

II. RELATED WORK

This section discussed the traditional methods corresponding to the survivability assurance, capacity maximization, traffic handling and the power consumption minimization in IP-over WDM networks in detail. Link protection schemes were enabled in research studies to safeguard the network from the link failures. *Gosavi*and *Pinghat*(6) presented the survey of routing methodologies to avoid the issues such as link failures and power outage in the single link cut set approach. The provision of backup paths leads to the insignificant loss of data. With the consideration of the network traffic and maintenance of the high-level service availability, survivability of the network is the major requirement for the optical networks. *Kumar* and *Garg*(7) presented the critical analysis of restoration methods for the optical networks. They presented the Net2Plan tool with its features and framed the problems as mathematical programming models to reconfigure and re-establish the communication upon the failures. The network reliability and resilience were considered as the key design parameters for the IP-over WDM. *Seoane et al* (8) presented the continuous-time Markov chain model to characterize the failure propagation in the optical rings called Generalized Multi-Protocol Label Switching (GMPLS) rings. The propagation of failures along the ring interfacing neighbor models with the numerical evaluation assured the better performance effectively. The mapping of each link in the logical topology with the physical topology was the major issue in the survivability assurance in network devices. *Lin et al* (9) considered the two concepts such as weakly and strongly survivable routing through the mathematical formulations. They designed the survivable light-path routing and the addition of spare capacities to the physical links governs the logical demand maximization and the provision of guarantee of routability. The prediction of pair

of diverse routes that form the cycle during the arrival of new requests was the major issue in the traditional approaches. *Srikanth et al* (10) presented the hybrid adaptive survivability algorithm that combined the effects of the restoration and protection. The provision of optimal trade-off is in between the proactive protection and the dynamic restoration. They constructed the simulation environment in two ways such as NS-2 simulator and the MATLAB and compared their results of throughput and blocking probability.

The frequent utilization of the backup paths in IP network prevents the network from the failures. *Priyadarshini et al* (11) developed the Probabilistic Correlated Failure (PCF) model to measure the collision of the IP link failure on the dependability of backup paths. They used lightweight proactive source routing protocol for the exchange of information among the neighbor nodes with information update. The disjoint light paths are for some group of logical links. The prediction of cost effective design was tolerant against the set of selected failures in multi-layer IP-over WDM optical network. *Pedreno-Manresa et al*(12) addressed the latency problem through the multilayer planning algorithm to the IP-over WDM networks. The three major schemes such as IP-only restoration, 1+1 optical protection followed by restoration and the optical followed by IP-restoration to validate the proposed algorithm. *Thulasiraman et al* (13) addressed the augmentation problems based on the survivable mappings under the physical link failures. They showed the embedding of logical topology on the physical topology to achieve the survivability. The survivable logical topology routing problem was to route the each link in logical layer with the path link in the physical layer. *Zhou et al* (14) presented the unified Mixed Integer Linear Programming (MILP) formulation to minimize the number of logical links added to guarantee the survivable topology routing and maximize the connectivity of the logical topology and cross layer cut. The impact of unused capacity (Excess Capacity (EC)) on the cross layer network limited the network performance adversely. *Dikibiyik et al* (15) proposed the EC management techniques that exploited the EC management techniques in two ways as follows: connection preprovisioning algorithm (for minimum connection setup time) and the protection schemes deployment. They developed Integer Linear Programming (ILP) and heuristic algorithms for EC management.

Dikibiyik et al (16) extended the EC technique to the backbone networks to accommodate the traffic fluctuations and avoid the early capacity reservation. Three schemes such as preprovisioning, backup reprovisioning and hold-lightpath were employed to increase the connection set-up time. Connectivity maintenance with less power consumption was the major issue in both the backbone and IP-over WDM models. *Ebrahimzadeh et al* (17) proposed the five novel energy aware routing approaches with the objectives of minimization of energy consumption and network transitions simultaneously. The adjustments in input parameters provided the trade-off between the QoS parameters such as energy efficiency and the blocking rate respectively. The critical metric to decide the performance of hybrid optical switch nodes for burst switching was the power consumption. The empirical solutions from the mathematical programming models were not the best choice for power and cost efficiency. *Rhee et al* (18) introduced the substantial savings power and cost by using the passive-medium photonic switches. The packet loss rate was kept as low as possible based on the photonic switches utilization. The minimization in energy consumption was the laborious task that required periodical switch-on and off redundant links and devices in short periods. *Sarigiannidis et al* (19) proposed the cognitive power management technique that enhanced the decision making according to the data traffic. Using this type of technique, the high-accuracy was achieved with the significant energy savings. Based on the backup paths and the rerouted traffic, the packet forwarding was split up into two multiple backup and rerouted when the IP links were failure. The bandwidth consumption was maximum under such situation. *PreetiKudambal et al* (20) developed the energy saving scheme called MILP based on the virtual topology and the traffic grooming designs. The interfering of the normal traffic with the rerouted traffic was minimized with this approach. Based on the IP routes, the energy and cost efficient design was developed.

The connection holding time and the bandwidth availability were the major problems in the traffic grooming designs due to the improper resource utilization. *Santi et al* (21) split up the connections into two streams through multi-path routing and the fine tuning in traffic grooming designs. They proposed the various simulation algorithms in realistic scenarios reduced the number of connection blocking requests effectively. The presence of the underutilized light paths during the network operation increased the power consumption. Hence, the researchers were turned to deactivate or minimize the underutilized light paths. *Melidis et al* (22) proposed the prediction-based dynamic threshold virtual topology reconfiguration algorithm that calculated the individual high threshold values according to the loading conditions. They improved the light path capacity and the adaptability of the thresholding algorithm. The reconfiguration time (time required from disrupted to the sub-optimal state) during the load prediction-based threshold algorithm was maximum. Hence, *Kammamura et al* (23) proposed the light path configuration and optimization algorithms to reduce the reconfiguration time effectively. The Traffic Matrix (TM) formulation with the configuration order estimation supported the preferential formulation effectively. The tree formulation in the research studies governed the topological mapping from IP to physical layers. The prediction of Minimum Spanning Tree (MST) in the structural approach called graph connected edges was the major issue in the topology mapping. *Bui et al* (24) formulated the Degree Constrained Minimum Spanning Tree (DCMST) problem as the NP-hard problem. They employed the set of ants that

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traversed the graph and identified the set of candidate edges through the optimization algorithms. The search process of optimal solutions was highly dependent on the movement of ants and the information exchanged among them. *Sun et al* (25) made the search process as the independent for the optimal solutions. They introduced the local optimal algorithms to improve the performance of constructed MST. They employed the dynamic strategies such as dynamic ant, random perturbations and the max-min ant system to improve the superiority of the optimal algorithms. The brief review of traditional studies conveyed that the searching the path with maximum cost, power and energy were the major issues in the IP-over WDM. The signal conversion such as optical to electrical and the electrical to optical in intermediate nodes leads to the delay in burst sending and packet forwarding. Hence, this paper proposes the hybrid algorithms to alleviate the issues in IP-over WDM

III. MINIMAL PATH COST-BASED SURVIVABILITY (MPCS) MODEL FOR IP-OVER WDM

This section discusses the implementation details of proposed MPCS model for IP-over WDM. The data communicated among the nodes depend on the signal conversion from optical to electrical and electrical to optical that leads to delay in delivery of the packets to the destination. Fig. 1 shows the workflow of proposed MPCS model for break-free communication in IP-over WDM.

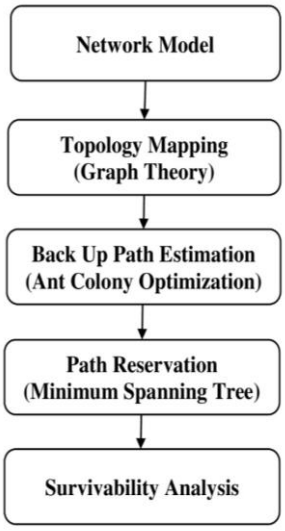


Fig. 1 Workflow of proposed MPCS

Initially, the network in the proposed method is modelled with the nodes and controllers. Then, the relationship between the virtual and physical topology is defined through the graph theory approach. The entire data communication is made as optical throughout the network and hence the data and its associated travelled path cannot be altered during the communication. Hence, the prediction of light paths according to wavelength and the alternate path during the failure conditions are the major tasks prior to communication. The controller placed within the specific group has the authority to monitor the light paths created among the nodes. The periodical update of link parameters such as path cost, energy of the nodes to the controller through the Link State Advertisement (LSA) facilitates the controlling action for break-free transmission. The formation of backup path using ACO based on the fitness function containing the delay and transition probabilities decreases the time for path search effectively. The reservation of light paths through MST construction minimizes the underutilized light paths that lead to reduction of energy consumption. At last, the survivability analysis is performed with the parameters such as number of burst send, packet end-to-end delay and the false path ratio against the existing methods. The integration of ACO-MST in proposed MCPS minimizes the path cost and delay in IP-over WDM network.

A. *Network Model*

The IP-over WDM optical network is modelled as the directed and connected graph (G) containing set of nodes (V) and the edges (E) correspond to the optical nodes and fibers respectively. The edge in graph theory has the capability to handle the two directed fibers oppositely to assure the data transmission in two directions respectively. A dedicated link is available between the directed fibers. Traditionally, the optical signal split up into several arbitrary number of signals through the splitter for multicast capability. The early development of wavelength converter and the high expensive optoelectronic conversion are the major issues in such splitter topologies. The full range optical concept introduced in this paper is able to convert the wavelength into any wavelength in an optical manner. The wavelength conversion also introduces the process and control delay. Hence, the assumptions are made prior to the proposal as follows:

- The delay during the conversion between the two different wavelength are same values
- The time required for the intermediate node is set it as zero for the absence of wavelength.

The link connecting the vertices $e_{ij} = (v_i, v_j)$ inherits the three parameters such as set of available wavelength($\Lambda(e_{ij})$), transmission delay $d(e_{ij})$ and the cost $c(e_{ij})$.

The representation of delay in interval instead of single value by the user and application in practical is the necessary task prior to the design. In this approach, the route between the multicast nodes is represented by the tree (T) and its total cost is defined by

$$Cost\ (T) = \sum_{e_{ij} \epsilon F_T} c(e_{ij}) \quad (1)$$

Where, F_T denotes the subset of edges $F_T \sqsubseteq E$

The delay includes two components such as link transmission delay and the wavelength conversion delay. Let us consider $P(s, d_i)$ be the path between the source and

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destination. The mathematical formulation of path delay is defined as follows

$$D = \left[\sum_{v_i \epsilon P(s,d_i)} t(v_i) + \sum_{e_{ij} \epsilon P(s,d_i)} d(e_{ij})\right] \quad (2)$$

Where, $t(v_i)$ denotes the wavelength conversion time delay for the vertices

The overall delay for the tree formulation is expressed as follows:

$$D_T = \max(D, \forall d_i \in D_{set}) \quad (3)$$

Where, D_{set} –set of delay values among source and destination

The available channels over the link are defined as the load and their illustration is done based on the link cost functions. The cost function in this model is formulated as

$$c(e_{ij}) = w - |\Lambda(e_{ij}| \quad (4)$$

The major objective of this paper is to minimize the cost at which the user satisfaction degree is high. The cost minimization is performed by constructing the sequential approaches such as graph theory, ACO and MST in following subsections.

B. Graph Theory-based Topology Mapping

The graph theory is used to map the virtual topology with the physical topology for IP-over WDM. Consider the graphs such as G_P and G_V represent the physical and virtual networks as follows: $G_P = (V_P, E_P)$ and $G_V = (V_V, E_V)$. The terms such as $V_V \sqsubseteq V_P$ predicts the relationship between the graph representing the physical topology and virtual topology. The interchangeable utilization of edges and links as well as vertices and nodes is based on the assumption such that both the physical and virtual networks are two-edge connected. The variables used in the graph-theory based mapping are described in Table I

TABLE I

VARIABLES IN GRAPH THEORY

S. No	Variables	Description
1	e, f, g	Physical Edges
2	u, v	Virtual Edges
3	i, j	Physical nodes
4	s, t	Virtual nodes
5	$i(u), j(u)$	Physical nodes of virtual link
6	$s(e), t(e)$	Virtual nodes of physical edge

The path predicted in the physical topology lies between the nodes having the virtual link is referred as light path and it provides the routing for the logical edge. The light path and corresponding virtual edge are disconnected if there any failure in physical edge is observed. The optimal virtual topology routing in IP-over WDM is defined as follows:

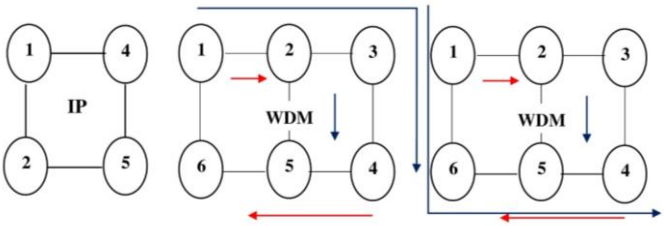
Definition 1: If the light path routings in the logical network has the better connectivity, then the virtual topology routing is regarded as an optimum process. The optimum routing path is set it as $P^* = (p^*(s,t): (s,t) \in E_V)$

Definition: The failure in set of physical links disconnects single logical cut set and it denoted as OL_{P^*}

Fig. 2 shows the example of optimal routing for IP-over WDM. The routings for the virtual edges are defined as $P = (p_{12}, p_{14}, p_{25}, p_{45})$. Each path in the set denotes the link between the following nodes illustrated in Fig. 2:

$$p_{12} = link(1,2)$$
$$p_{14} = link((1,6),(6,5),(5,4))$$
$$p_{25} = link(2,5)$$
$$p_{45} = link(4,5)$$

The connection flow prior to the failure is indicated in Fig. 2 (b). After the failure of (1, 2), the logical network in between these nodes is disrupted. Then, the alternate path among the nodes 1, 6, 5 and 4 is selected which is indicated in blue color. Then, the link between the nodes (4, 5) is disconnected that leads to overall disruption in logical networks. The failure links are denoted in red color.



(a) (b) (c)

Fig. 2 optimal routing for IP-over WDM

The logical network illustrated in Fig. 3 (a) includes the initial route formation (b) and the alternate path selection during the failure (c). The light path has the ability to identify the failure in the set OL. Once the paths are formed, the search of back up paths during the failure undergoes the optimization process to minimize the cost.

C. Backup path Estimation

The total cost incurred with the optical network during the demand satisfaction is less which is the major objective of the proposed MPCS. This problem is modelled as the multi-objective problem through the ACO(26)-based back up path estimation. The problem formulation includes the variables in Table II for ACO-based backup path estimation.

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TABLE II

ACO VARIABLES

S. No	Variables	Description
1	t	Source node
2	n	Number of demand nodes
3	d_j	Demand of each node
4	y_{ijh}	$\{1, if\ x_{ijh} > 0\}$ $\{0, if\ x_{ijh} = 0\}$
5	x_{ijh}	Flow on arc
6	f_{ij}	Cost on arc
7	N	Set of n+1 nodes
8	H	Hop parameter

The total cost to be minimized includes the cost corresponding to the usage of arcs and the routing flow described as follows:

$$min: \sum_{i\in N} \sum_{j\in N(t)} \sum_{h=1}^{H} f_{ij}(x_{ijh}, y_{ijh}) \quad (5)$$

The constraints to satisfy the equation (5) are expressed as follows:

$$\sum_{i\in N} \sum_{h=1}^{H} y_{ijh} = 1 \quad (6)$$

$$\sum_{i\in N} x_{ijh} - \sum_{i\in N(t)} x_{ij,h+1} = d_j \sum_{i\in N} y_{ijh}, \quad \forall_{j\in N(t)}, \forall_{h\in(1,\dots H-1)} \quad (7)$$

$$y_{ijh} \le x_{ijh} \le D.y_{ijh}, \forall_{i\in N}, \forall_{j\in N\{t\}}, \forall_{h\in\{1,\dots,H\}} \quad (8)$$

$$x_{ijh} \ge 0, \forall_{i\in N}, \forall_{j\in N\{t\}}, \forall_{h\in\{1,\dots,H\}} \quad (9)$$

$$y_{ijh} \in \{0,1\}, \forall_{i\in N}, \forall_{j\in N\{t\}}, \forall_{h\in\{1,\dots,H\}} \quad (10)$$

Fig. 3 shows the process flow of ACO algorithm for back up path estimation.

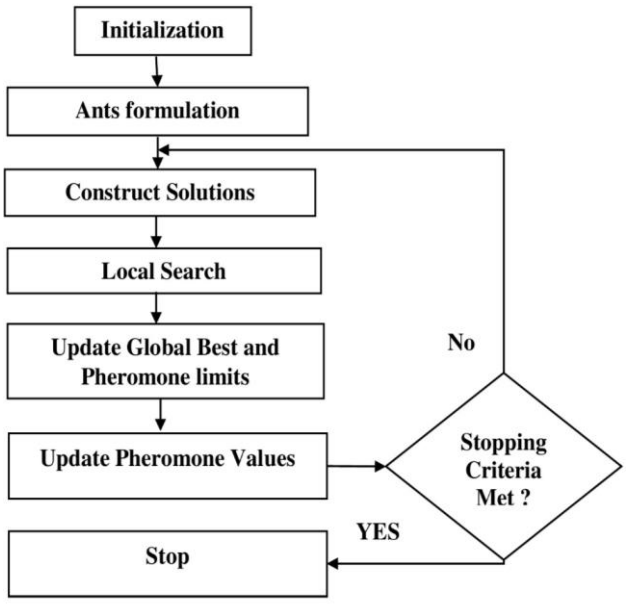


Fig. 3 ACO algorithm

Initially, the ant selects the existing arc linked the source and demand nodes. Then, the ant selects the sequential arcs and the link added to the partial solution. The length of the path (l) is calculated during the time of arc is added to the partial solution. If the maximum length is reached, then the arcs considering the parent node are excluded from the viable arc sets. The solution of the arc is selected based on the transition probability is defined by,

$$P_{i,j} = \begin{cases} \frac{\varphi_{i,j}}{\sum_{i\in N_i} \varphi_{i,j}} & if\ j \in N_i \\ 0 & if\ j \notin N_i \end{cases} \quad (11)$$

Where, $\varphi_{i,j}$ – pheromone

N_i - Set of neighbors

Subject to the constraint of:

$$\sum_{j\in N_i} P_{i,j} = 1, \quad i \in [1, N] \quad (12)$$

During the movement from node $i$to j, the changes in the pheromone are expressed as

$$\varphi_{i,j} = \varphi_{i,j} + \Delta\varphi \quad (13)$$

Using this way, the backup path is computed if the link failure occurs. The storage of the backup paths is the next stage to alleviate the issue in energy consumption.

D. MST-based Path Reservation

The path with the required wavelength is reserved to remove the underutilized path during the communication efficiently reduces the energy consumption. The Minimum Spanning Tree (MST)(24) is helpful to restore the required path. The MST-based formulation stores the backup paths effectively. Thereby the search cost is reduced that leads to reduction in energy consumption effectively.

MST based path reservation

Step 1: Assume the virtual and physical topology as identical
Step 2: Initialize the set of light paths as (S_{LP})
Step 3: **For each**S_{LP}
Step 4: $Load_{LP}(i) = Load_{max}$
Step 5: **End For**
Step 6: Initialize LP=sorted (LP_V) // light paths of virtual topology
Step 7: **While** ($LP \neq empty$)
Step 8: Remove the first element in LP
Step 9: Reroute the traffic from Step 2 at time T_i
Step 10: **If** $Load_{LP}(j) > Load_{LP}(i)$
Step 11: Restore the first path in LP
Step 12: **Else**
Step 13: Go to step 7
Step 14: Broadcast the link parameters to controller through LSA
Step 15: Compute backup path using ACO
Step 16: **End While**
Step 17: **For each**$source - destination\ pair$

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Step 18: Select the first successful path from the edge-disjoint paths
Step 19: **End for**
Step 20: **For each** selected path
Step 21: **If** (wavelength =reserved)
Step 22: Select the alternate path
Step 23: **Else**
Step 24: Select the path
Step 25: **End If**

IV. Survivability Analysis

The survivability analysis of proposed MPCS model is validated with the help of NSFNET topology containing 6,14, 24 nodes. The configuration parameters for the simulation are illustrated in Table III.

TABLE III
SIMULATION PARAMETERS

S. No	Simulation parameters	Values
1	Network topologies	NSFNET (6,14,24)
2	Number of channels per link	4 (3 – Data 1-Control)
3	Bandwidth per channel (Gbps)	1
4	Packet Size (bytes)	1250
5	Packet interarrival time	Exponential
6	Timer Threshold	
	Minimum	0.001
	Maximum	0.006
	Initial (t)	0.004
7	Burst Threshold (bytes)	
	Minimum (m)	1500
	Maximum	100000
	Initial (l)	60000
8	Offered Load	
	Minimum	0.1
	Maximum	1
	Increment	0.1

The network topology includes bidirectional source and destination pairs respectively. The nodes in network topologies have the ability to transmit and receive the information on distributed traffic. The network offered load depends on the traffic generated by the user and the link capacity used to validate the performance of proposed MPCS algorithm. The mathematical formulation for the load offered is expressed as follows:

$$Load_{offered} = \frac{\sum_{i=1}^{m} Load_i}{\sum_{j=1}^{n} cap_j} \quad (14)$$

Where, $Load_i$ – Amount of traffic generated by the user
cap_j – Link capacity
n – Total number of links available
m – Number of active users in the network

The evaluation metrics to validate the performance are burst end-to-end delay, failure path selection ratio, packet end-to-end delay, number of bursts send and the blocking rate. The comparative analysis between the proposed MPCS with the existing algorithms such as TSP(27), MST, MST-LWUP (17)shows the effectiveness of MPCS in IP-over WDM.

A. *Burst End-to-End Delay*

The overall time duration for the burst transferred from ingress node to egress node refers burst end-to-end delay. The variations of burst end-to-end delay with respect to the offered load variations corresponding to proposed MPCS and existing algorithms(17)are illustrated in Fig. 4.

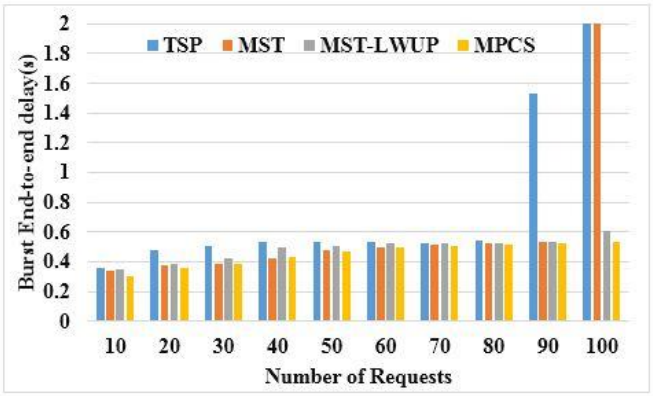


Fig. 4 Burst end-to-end delay analysis

With an increase in connection requests, the time duration for the burst traveling from the ingress node to egress node is increased. In existing algorithms, the MST-LWUP algorithm provides the less end-to-end delay like 0.61 s which is lesser than the TSP (2.5s) and MST-LWUP (2.01s) for maximum connection requests (100). But, the ACO-MST modeling in proposed MPCS reduces the computational size of reserved channels and hence, the end-to-end delay values are less. The burst end-to-end delay value of proposed MPCS is 0.53s which is 13.11 % reduction compared to existing MST-LWUP algorithm.

B. *Failure Path Selection Ratio*

The ratio of number of paths are failed with respect to the number of paths available is defined by the measure called failure path selection ratio. The reduction in a number of failure paths provides the minimum ratio that specifies the effectiveness of the algorithm.

The variations of failure path selection ratio values are with respect to the offered load size graphically illustrated in Fig. 5.

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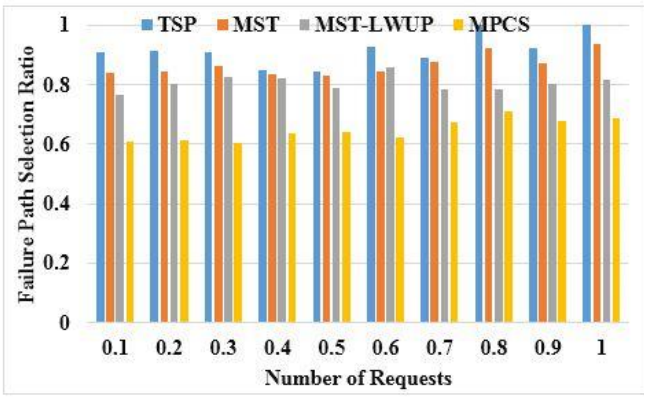


Fig. 5 Failure Path Selection Ratio

With an increase in load offered, the ratio is gradually decreased. In existing algorithms, the MST-LWUP algorithm provides the less ratio for the minimum (0.1) and maximum offered load (1) like 0.766095 and 0.8186 compared to TSP and MST respectively. But, the path reservation based on ACO-MST in proposed MPCS reduces the ratio values effectively. The values of proposed MPCS are 0.610732 and 0.687027 for minimum and maximum offered load which is 20.28 and 16.07 % reduction compared to existing MST-LWUP algorithm.

C. *Packet End-to-End delay*

The packet end-to-end delay comprises three delays such as burst disassembly, burst end-to-end delay and the queuing delay as follows:

$$Packet_{Delay} = BDA_{delay} + B_{delay} + Q_{delay} \quad (15)$$

Where, BDA_{delay} – Burst disassembly delay

B_{delay} – Burst end-to-end delay

Q_{delay} – Queuing delay

The increase in load will increase the packet end-to-end delay gradually. The variations of packet end-to-end delay with respect to the offered load size variations are graphically illustrated in Fig. 6.

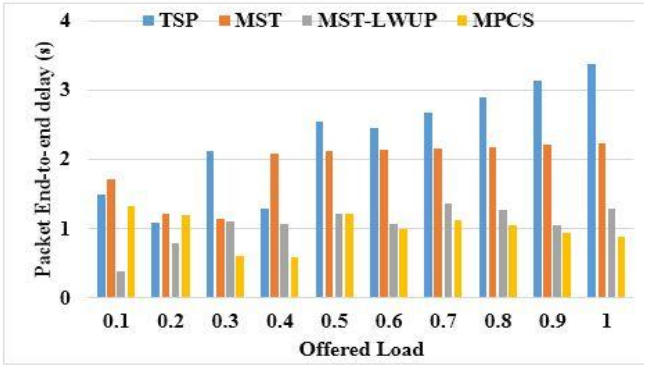


Fig. 6 Packet end-to-end delay analysis

The packet end-to-end delay values are less for the minimum offered load in MST-LWUP compared to the traditional TSP and MST. The MST based reservation and the ACO formulation based on the wavelength reduced the packet end-to-end delay.

D. *Number of Bursts Sent*

With an increase in offered load size, the number of bursts sent gradually increased in both the existing and proposed algorithms. The variations of a number of bursts with respect to the offered load size variations are graphically illustrated in Fig.7

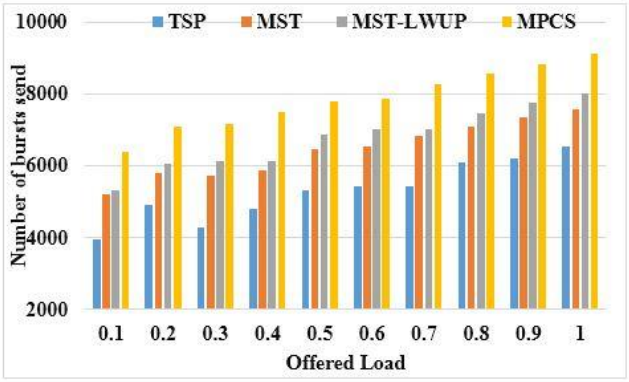


Fig. 7 Analysis of number of bursts sent corresponding to load variations

In existing methods, the MST-LWUP provides maximum number of bursts sent compared to TSP and MST. The number of bursts sent for MST-LWUP are 5330 and 8031 for minimum (0.1) and maximum (1) offered load. But, the hybrid optimizations in the proposed MPCS increased the count of bursts sent significantly. The value of bursts is 6376 and 9331 for proposed MPCS which is 16.41 and 13.93 % improvement compared to the existing MST-LWUP algorithm.

E. *Blocking Probability*

The ratio of number of requests blocked to the total number of calls generated is referred as blocking rate. The number of requests blocked depends on the path reserving capability. With the variations of requests, the variations of blocking probability are illustrated in Table IV.

TABLE IV

BLOCKING PROBABILITY ANALYSIS

Number of requests	TSP	MST	MST-LWUP	MST-LWUP4	MPCS
10	0	0	0	0	0
20	0.0040	0.0030	0.0020	0.0030	0.0050
30	0.0273	0.0267	0.0160	0.0253	0.0243
40	0.0810	0.0755	0.0635	0.0780	0.0620
50	0.1332	0.1368	0.1196	0.1360	0.0874
60	0.1793	0.1843	0.1717	0.1790	0.1159

BUPT

70	0.2219	0.2349	0.2243	0.2311	0.1444
80	0.2676	0.2670	0.2638	0.2650	0.1729
90	0.3132	0.3208	0.3144	0.3180	0.2014
100	0.3589	0.3678	0.3456	0.3436	0.2299
110	0.4045	0.4149	0.3718	0.3747	0.2584
120	0.4502	0.4619	0.4098	0.4112	0.2869
130	0.4958	0.5089	0.4369	0.4398	0.3154
140	0.5415	0.5560	0.4748	0.4523	0.3439
150	0.5871	0.6030	0.5085	0.4807	0.3724
160	0.6328	0.6501	0.5421	0.4886	0.4009
170	0.6784	0.6971	0.5758	0.5112	0.4294
180	0.7241	0.7442	0.6095	0.5334	0.4579
190	0.7697	0.7912	0.6431	0.5452	0.4864
200	0.8154	0.8382	0.6768	0.5549	0.5149

Under the maximum size of requests (200), the blocking probability for MST-LWUP and MST-LWUP4 are 0.6768 and 0.5549. But, it is minimum in proposed MPCS such as 0.5149. The comparative analysis between the proposed MPCS and MST-LWUP shows that the blocking probability of proposed MPCS is reduced by 23.92 and 7.2 % compared to MST-LWUP and MST-LWUP4 respectively.

V. CONCLUSION

This paper discussed the issues in the network survivability against the link failures and excessive power briefly. The major implications observed from the literal review regarding the preservation schemes are OEO conversion, traffic and processing overhead. The lack of instant update of link parameters and the periodical maintenance of link were the major reasons for IP-over-WDM network. This paper proposed the hybrid algorithms such as MST and ACO on the graph-based structure to maintain the link parameters effectively. The delay-based pheromone formulation in this paper reduced the time consumption for alternate route estimation under the link failures. The combination of ACO and MST predicted the successive path for break-free data communication. The LSA information to the controllers played a major role in the IP-over-WDM through optical links. The investigation of performance analysis of the proposed work against the existing methods in terms of various parameters such as delay and number of burst send confirmed the effectiveness of proposed work in network survivability assurance in IP-over-WDM. The comparative analysis of the proposed work with the existing methods regarding the parameters of packet end-to-end delay, burst end-to-end delay, failure path selection ratio and the number of burst send assure the effectiveness of proposed work in the optical communication on IP-over-WDM network.

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