FORMAT FOR COMPLETION REPORT
PART - 1

1. Title of the project: Development of Secured and Reliable Spectrum Allocation Schemes for Next-Generation Elastic Optical Networks
2. Implementing Organisation: Tezpur University, South Asian University, IIIT Naya Raipur
3. DeitY Sanction No. and Date: 13(34)/2020-CC&BT, dtd. 11.03.2021

4(a) Total Budget Outlay: Original: Rs. 86.31624 lakh Revised, if any
(b) Duration of project : 11.03.2021 to 30.04.2025
(c) Date of completion and reasons for delay, if any :

5. Total funds spent under various approved budgetary Heads/actual expenditure. Reasons for deviation, if any (as per enclosed Table 1) : Details provided in Table 1

Approved Amt (in Lakh): 38.65538 (Tezpur Univ), 29.18696 (SAU), 21.16264 (IIITNR)
Released Amt (in Lakh): 38.65538 (Tezpur Univ), 27.88164 (SAU), 9.42521 (IIITNR)
Expenditure (in Lakh): 38.51962 (Tezpur Univ), 26.63871 (SAU), 9.42521 (IIITNR)

6. Details of equipment/assets acquired out of DeitY funds with the name of equipment, sources of supply, total cost/whether Indian or imported (as per enclosed Table 2.1, 2.2 and 2.3) : Details provided in Table 2.1,2.2 & 2.3

7. Details of manpower associated with the project (as per enclosed Table 3) : Details provided in Table 3

8. Details of year-wise audited statement of accounts and utilization certificates submitted to DeitY (as per G.F.R.19 & 19A) : Details in attached documents

PART – II

1. Project work and achievements:

a. Executive Summary :

Elastic optical networks (EONs) [Gerstel et al., 2012, Chatterjee et al., 2015] have been considered as a potential solution for ever-increasing network bandwidth demands of clients. EONs are vulnerable to several types of security attacks, typically aimed at either disrupting the service or gaining unauthorized access to data. In such situations, the network service providers can incur huge data and revenue losses. Therefore, awareness about what are the vulnerabilities and threats associated with the underlying design of EONs and how those can be mitigated effectively are major concerns for designing an effective secure next-generation EONs [Furdek et al., 2014]. Nowadays, SDN is being adopted in optical networks to improve the network performance [Chatterjee et al., 2018]. However, SDN might also introduce certain vulnerabilities to the network. Therefore, the overall objective of the project is to investigate the reliability issues and security vulnerabilities in EONs and develop mechanisms which will improve reliability in resource allocation and enable secured data transmission in next-generation EONs. The following are the main subtasks under the proposed project objectives.

- To investigate possible architectural changes in the network that will improve the performance efficiency of conventional optical networks and offer better network resource utilization.
- To develop spectrum management schemes for improving network efficiency and reliability during resource allocation. The spectrum management schemes either consider defragmentation or non-defragmentation strategies based on the availability of equipment and filtering components.
- To develop a secure communication protocol to secure transmitting confidential data from end-user to data centers. The proposed architecture considers support for three different models correspond to three different levels of security, such as high, medium and low trust-worthy security systems. The security levels to be implemented by the proposed architecture will based on the demand of an organization. In this prospective, the proposed architecture needs to implement three different security protocols for provisioning different levels of security.
- To study and develop techniques to protect EONs from all types of high-level security attacks including - Man- in-the-Middle attack, Denial of service attack, Impersonation attack, Key compromise attack, and Replay attack. The major difficulty faced during design of a security protocol is to devise mechanisms which can address all types of security attacks. Therefore, knowing what the possible attacks are, how they behave and how they can be mitigated, is paramount to successful design of any security mechanism.
- To provide security in SDN deployment by providing high-level security protection on possible attacks on data plane layer, controller layer, and SDN layer. In the current scenario, most of the organizations demand for software-defined networking (SDN)-enable network infrastructure for several benefits.
- To develop a light-weight protocol to store data securely using cryptographic techniques for three levels of security provisioning, which are high, medium, and low, mentioned in the proposed model.

b. Project status with respect to milestones

Activity	Targets	Achievements	Reason for variation
Tezpur University			
1. Brainstorming among PIs, manpower hiring, basic setup, procurement process for capital equipment, and review of literature	1.1 Manpower Hiring 1.2 Procurement of capital equipment 1.3 Literature review	1.1.1. Manpower hiring is done in the month of November'2021 1.2.1. Procurement of capital equipment is done 1.3.1. Literature review is carried out for state-of-the art work for the project	
2. Study on different architectures of elastic optical networks (EONs) considering Indian context. 3. Understanding issues and cryptographic algorithms in the context of EONs.	2.1 Literature review 3.1 Literature review for security issues	2.1.1. Literature review is carried out for the study 3.1.1. In context of EON, literature review for security issues is carried out in collaboration	
4. Routing protocol design: Finding suitable primary and backup routes per request. 5. Exploring existing solutions for secure communication protocols in the context of EONs.	4.1 Literature review in collaboration 4.2 Development of protection schemes in SEON	4.1.1. Towards the design, defragmentation based on route partitioning in 1+1 protected EON is done in collaboration 4.1.2. Resource allocation in SEON based on dynamic traffic. 5.1.1 A literature survey is carried out in collaboration	
6. Spectrum allocation: Develop a suitable spectrum allocation policy per request, which handles the issues of spectrum fragmentation	6.1. Development of fragmentation-aware routing and spectrum allocation scheme	6.1.1. Considering spectrum fragmentation, routing and spectrum allocation problem is being addressed in terms of optimization problem formulation.	

	6.2. Development of machine learning assisted spectrum allocation scheme	6.2.1. Spectrum allocation: Development of machine learning assisted spectrum allocation scheme to reduce spectrum fragmentation and maintain fair allocation of spectrum	
7. Fragmentation-aware resource allocation with spectrum partitioning in elastic optical networks	7.1. Formulation of static spectrum allocation problem as optimization problem in partitioned spectrum scenario. 7.2. Development of a fragmentation metric in partitioned spectrum scenario.	7.1.1 Formulated an optimization problem for static spectrum allocation with spectrum partitioning. 7.1.2. Proved NP-Completeness of the problem formulated in task 7.1.1. 7.2.1. Developed a fragmentation metric to measure the fragmentation level in partitioned spectrum scenario. 7.2.2 Developed a fragmentation and holding time-aware spectrum allocation scheme in partitioned spectrum scenario. 7.2.3. Performance evaluation of the scheme developed in 7.2.2.	
8. Demand-grouping and spectrum-partitioning-Based spectrum allocation in EONs	8.1. Development of demand grouping-based fair spectrum partitions.	8.1.1. Formulated an optimization problem to optimally group demands and determine fair spectrum partitions based on spectrum requirements.	
9. Formulate routing and resource allocation problem as optimization problem for dynamic scenarios	9.1. Development of defragmentation based routing and slot allocation scheme.	9.1.1. Towards the design, defragmentation based routing and slot allocation EON is done in collaboration 9.1.2. Fragmentation-aware continuity and contiguity preserving spectrum allocation scheme for Elastic Optical Networks (EONs) in dynamic traffic scenarios.	
10. Develop a protocol for secure communication in context of proposed elastic optical networks	10.1. Development of Symmetric Key Distribution Technique	10.1.1. In the context of EON a Symmetric Key Distribution Technique between Nodes is developed in collaboration	

11. Develop approximation algorithms to address intractability issues for large networks	11.1. Literature Survey 11.2. Development of fragmentation aware heuristic algorithms	11.1.1. A literature survey on approximation algorithms is carried out 11.1.2. Develop heuristic algorithms to manage fragmentation for large scenario	
12. Theoretical analysis for proposed fragmentation scheme and approximation algorithms	12.1. Analysis of schemes and algorithms	12.1.1. Analysis of the introduced algorithms	
13. Performance evaluation of proposed fragmentation scheme considering Indian network scenarios	13.1. Performance evaluation of proposed schemes	13.1.1. Formulated routing and resource allocation problem in spectrum partitioned EON as optimization problem for static scenarios. 13.1.2. Fragmentation aware resource allocation with spectrum partitioning in EON. 13.1.3. Fine-tune the obtained experimental results in the context of the Indian Network	
14. Develop a protection scheme considering effective resource allocation in SEON	14.1. Development of protection scheme considering effective resource allocation in SEON	14.1.1. Effective Resource Allocation in SEON based on Heterogeneous Traffic Demands 14.1.2 Modulation-Aware Asymmetrical Traffic Splitting for Heterogeneous Demands for SEON. 14.1.3. Power Consumption-Aware Asymmetrical Traffic Splitting in SEON Based on Traffic Demands 14.1.4. Fragmentation-Aware Spectrum Allocation for Dynamic Traffic in Elastic Optical Networks. 14.1.5. A Survey of Failure Scenarios and Solutions 14.1.6. State-aware hybrid protection scheme considering splitting of demands in SEON based on heterogeneous demands.	

multi-spatial multi-spectrum . dimension-based spectrum allocation problem for dynamic connection in SS-EONs	Development of a QoT-aware lightpath provisioning model for elastic optical networks, considering Multi-Band	Formulated the multi-spatial multi-spectrum dimension-based spectrum allocation problem for dynamic connection in SS-EONs. - Develop a QoT-aware lightpath provisioning model for elastic optical networks, considering Multi-Band (C and L bands)	
South Asian University:			
1. Brainstorming among PIs, manpower hiring, basic setup, procurement process for capital equipment, and review of literature	1.1 Manpower Hiring 1.2 Procurement of capital equipment 1.3 Literature review	1.1.1. Manpower hiring is completed. 1.2.1. Procurement of capital equipment is done except the server 1.3.1. Literature review is carried out for state-of-the art work for the project	
2. Study on different architectures of elastic optical networks (EONs) considering Indian context. 3. Understanding issues and cryptographic algorithms in the context of EONs.	2.1 literature review 3.1 Literature review for security issues	2.1.1. Literature review is carried out for the study 3.1.1. In context of EON, literature review for security issues is carried out in collaboration	
4. Routing protocol design: Finding suitable primary and backup routes per request.	4.1. Development of protection scheme considering defragmentation.	4.1.1. Towards the design, defragmentation based on route partitioning in 1+1 protected EON is done in collaboration	
5. Spectrum allocation: Develop a suitable spectrum allocation policy per request, which handles the issues of spectrum fragmentation 6. Development ML assisted spectrum allocation to reduce fragmentation In EON	6.1. Development of fragmentation-aware routing and spectrum allocation scheme 6.2. Development of machine learning assisted spectrum allocation scheme	6.1.1. Considering spectrum fragmentation and reliability, the routing and spectrum allocation problem is being addressed in terms of optimization problem formulation. We are working on the formulation of the problem 6.1.2. Proposed link state aware spectrum allocation scheme for EON. 6.2.1. Spectrum allocation: Development of machine learning assisted spectrum allocation scheme to reduce	

		spectrum fragmentation and maintain fair allocation of spectrum	
7. Formulate routing and resource allocation problem as optimization problem for dynamic scenarios 8. Development of RSA algorithm for EON Considering Physical layer impairments.	7.1. Development routing and spectrum allocation algorithm 8.1. Development routing and spectrum allocation algorithm	7.1.1. Towards the design, defragmentation based routing and slot allocation EON is done in collaboration 8.1.1. Towards routing and spectrum allocation algorithm development is carried out in collaboration	
9. Performance evaluation for static scenarios: Solving ILP by LP solvers including CPLEX Optimizer	9.1. Performance evaluation	9.1.1. Performance of Defragmentation Approach Based on Route Partitioning in 1+1 Protected EON is carried out in collaboration	
10. Exploring how to integrate SDN framework in the proposed EONs	10.1. Literature survey	10.1.1. A literature survey on SD-EON is carried out in collaboration	
11. Develop approximation algorithms to address intractability issues for large networks	11.1. Development of approximation algorithm	11.1.1. A literature survey is on approximation algorithm is carried out 11.1.2. Develop a heuristic algorithm to address the intractability for large scenarios.	
12. Theoretical analysis for proposed fragmentation scheme and approximation algorithms 13. Blocking Probability Analysis Modeling in EON 14. Fragmentation-aware learning spectrum allocation scheme in EON	12.1. Analysis of proposed results and proposed algorithms 14.1. Development of reinforcement learning schemes considering fragmentation	12.1.1. Analysis of the introduced algorithms 12.1.2. Blocking Probability Analysis Modeling in Elastic Optical Networks in presence of Crosstalk 14.1.1. Future fragmentation-aware reinforcement learning (RL) based solution for spectrum allocation in EON. We are working on the formulation of the problem.	
15. Performance evaluation of proposed fragmentation scheme considering Indian network scenarios	15.1. Development of fragmentation aware schemes		

	15.2. Analysis of obtained results 15.3. Development of QoT aware models in EON	15.1.1. Formulated routing and resource allocation problem in spectrum partitioned EON as optimization problem for static scenarios 15.1.2. Fragmentation aware resource allocation with spectrum partitioning in EON 15.2.1. Fine-tune the obtained experimental results in the context of the Indian Network 15.3.1. Develop a QoT-aware lightpath provisioning model for elastic optical networks, considering Multi-Band (C and L bands) 15.3.2. Evaluate lightpath provisioning using Multi-Band technology within the Indian Network context	
16. Extended study on fragmentation aware resource allocation with spectrum partitioning in Elastic Optical Networks	16.1. Development of fragmentation aware resource allocation with spectrum partitioning in Elastic Optical Networks	16.1.1. Extended study on fragmentation aware resource allocation with spectrum partitioning in Elastic Optical Networks 16.1.2. Demand-Grouping and spectrum-partitioning-based spectrum allocation in Elastic Optical Networks 14.1.12. A Survey on deep reinforcement learning (DRL) based resource allocation elastic optical networks. 14.1.13. Developed C+L band EON environment, including state and action space, rewards, and the transition model.	

		14.1.14. Developed Graph attention network and Transformer-based spectrum allocation scheme for C+L band EONs.	
IIIT Naya Raipur			
1. Brainstorming among PIs, manpower hiring, basic setup, procurement process for capital equipment, and review of literature	1.1 Manpower Hiring 1.2 Procurement of capital equipment 1.3 Literature review	1.1.1. Manpower hiring is done in the month of November'2021 1.2.1. Procurement of capital equipment is done 1.3.1. Literature review is carried out for state-of-the art work for the project	
1. Understanding issues and cryptographic algorithms in the context of EONs.	2.1 literature review 2.2 Literature review for security issues	2.1.1. Literature review is carried out for the study 2.2.1. In context of EON, literature review for security issues is carried out in collaboration	
2. Exploring existing solutions for secure communication protocols in the context of EONs.	3.1 Literature review to find the security concerns in the context of secure communication in the EoNs	3.1.1 The literature review is carried out and pointed security concerns in the context of security communication among optical nodes in elastic optical networks.	
3. Develop a protocol for secure communication in context of proposed elastic optical networks	**4.1:** Design of an architecture for elastic optical networks (EoNs) enabling secure node authentication. **4.2:** Development of a robust authentication protocol tailored for EoNs. **4.3:** Implementation of secure communication mechanisms among nodes, ensuring authentication and protection against unauthorized access in EoNs.	**4.1.1** The architecture has been designed specifically for elastic optical networks (EoNs). **4.2.2** The authentication protocol has been developed and its robustness has been demonstrated through security analysis. **4.3.3** A secure communication protocol has been designed to meet the defined security objectives. **Note:** One conference paper from this work has been published in Springer proceedings.	
4. Quantum-Safe Authentication Protocol with Key Management for	5.1 Design Q-AuthSDN for quantum-safe mutual	5.1.1 Achieved quantum-safe mutual authentication and key exchange in SDN-based	

Software Defined Optical Network	authentication and key exchange in SDN. 5.2. Integrate protection against eavesdropping, replay, and MITM attacks. 5.3. Ensure unlinkability, anonymity, integrity, and unconditional security. 5.4 Simulate Q-AuthSDN using Qiskit. 5.5 Evaluate performance against existing protocols. 5.6 Demonstrate practical use without requiring full quantum capabilities in all nodes.	optical networks. 5.2.12 Ensured strong security guarantees, including identity privacy, message unlinkability, and non-repudiation. 5.3.1 Provided resilience against major attacks like eavesdropping, replay, and MITM. 5.4.1 Demonstrated superior performance with reduced communication and computation overhead. 5.5.1 Enabled practical deployment by removing the need for full quantum capabilities in all network nodes. 5.6.1 Validated the protocol through simulation using Qiskit. Note: This work has been submitted in the IEEE Transaction journal and it is currently under review.	

Summary

(4.1.3) This work addresses the challenge of high power consumption and inefficient modulation selection in existing state-aware STD models for survivable elastic optical networks (SEON). While symmetrical traffic splitting over link-disjoint paths improves survivability, current models overlook the impact of modulation format and number of splits on power usage. To address this challenge, this work proposes Power Consumption-Aware Symmetrical Traffic (PCST) splitting model that integrates distance-adaptive modulation and state-aware allocation strategies to minimize power consumption and blocking probability while efficiently handling heterogeneous traffic demands.

Publication : *SARMA, A. K., Deka, S. K., & Sarma. N. Power consumption-aware symmetrical traffic splitting based on heterogeneous traffic demands. 3rd International Conference on Innovations in Management, Science, and Technology (ICIMST-2024).(Accepted)*

(12.1.1.) In this work we address the challenge of high blocking probability and inefficient resource usage in SEON caused by traffic heterogeneity and spectrum fragmentation. To overcome this, it proposes two models state-aware Symmetrical (STD) and Asymmetrical (ASTD) Traffic Demand Splitting that combine link-disjoint multipath routing, state-aware allocation strategies (First-Fit, Best-Fit, Worst-Fit) and traffic splitting techniques. These models aim to improve connection acceptance rate and resource utilization by dynamically splitting traffic based on path availability and traffic size while ensuring network survivability.

Publication: *SARMA, A. K., Deka, S. K., & Sarma, N. (n.d.). Effective resource allocation in SEON based on heterogeneous traffic demands. IEEE 2nd World Conference on Communication & Computing 2024.(Published)*

(12.1.2) This work addresses the challenge of efficient resource allocation and high blocking probability in SEON, particularly under heterogeneous traffic demands. Existing models like state-aware ASTD leverage asymmetrical traffic splitting and link-disjoint multipath routing with fixed modulation formats. However, they fail to consider transmission distance when selecting modulation formats, limiting spectrum efficiency. To address this challenge, this work proposes a Modulation-Aware Asymmetrical Traffic Demand (MASTD) model that integrates distance-adaptive modulation with state-aware allocation strategies. The objective is to reduce blocking probability and enhance spectrum utilization by dynamically adapting modulation formats based on path distances and traffic demand sizes. A MILP formulation is provided for optimal path selection and traffic allocation, supported by a heuristic solution to handle scalability in large networks.

Publication : *SARMA, A. K., Deka, S. K., & Sarma. N. Modulation-Aware Asymmetrical Traffic Demand Splitting Based on Heterogeneous Traffic Demands. IEEE 16th International Conference on Computational Intelligence and Communication Networks (CICN) 2024 .(Published)*

(12.1.3) The increasing demand for power-efficient and high-capacity optical communication systems has elevated the importance of SEON. Traditional traffic allocation strategies fail to balance power consumption and resource utilization, especially under heterogeneous and high-volume traffic demands. Existing models like state-aware ASTD address survivability but overlook power consumption during modulation and splitting. To address this challenge, this work proposes the Power Consumption-Aware Asymmetrical Traffic (PCAT) splitting model, which integrates distance-adaptive modulation and state-aware allocation strategies to minimize power consumption (PC) and blocking probability (BP). The model dynamically splits traffic asymmetrically based on path availability and transmission distance, selecting suitable modulation formats to optimize spectrum and energy efficiency. Simulation results show that PCAT significantly reduces both BP and PC compared to existing models, making it a power-efficient and scalable solution for SEON.

Publication : *SARMA, A. K., Deka, S. K., & Sarma. N. Power Consumption-Aware Asymmetrical Traffic Splitting in SEON Based on Traffic Demands. IEEE 16th International Conference on Computational Intelligence and Communication Networks (CICN) 2024.(Published).*

(12.1.5) This work presents a comprehensive survey on survivability strategies in Elastic Optical Networks (EON), focusing on the challenges posed by various failure scenarios such as link, node, path, and hardware failures. While techniques like Dedicated Path Protection, Shared Backup Path Protection, segmented restoration, and p-cycle protection have been widely studied, they often involve trade-offs in terms of recovery speed, resource utilization, and scalability. The core problem lies in the absence of a unified framework that can efficiently handle all failure types while maintaining high spectral efficiency and low blocking probability. To address this challenge, this work analyzes state-of-the-art protection and restoration schemes and proposes a hybrid protection model that integrates state-aware traffic splitting with a vulnerability scoring system.

This model aims to improve survivability, optimize spectrum usage, and reduce blocking probability, offering valuable insights for the development of future intelligent and resilient SEON architectures.

Publication : *Sarma, A. K., Deka, S. K., & Sarma, N. (2025). Survivable Elastic Optical Network: A Survey of Failure Scenarios and Solutions [Manuscript submitted to Optical Switching and Networking, Under Review].*

(12.1.6) SEON faces challenges in efficiently handling heterogeneous traffic demands and ensuring resilience against single-link failures. Existing models either incur high protection overhead or fail to adapt to traffic diversity and failure scenarios. Current approaches do not effectively split and protect traffic under varying demands without increasing resource usage or blocking probability. To address this challenge, this work proposes a State-Aware Asymmetrical Hybrid Protection (AHP) model that combines asymmetrical traffic splitting, link-disjoint multipath routing and a shared backup path with vulnerability-aware selection. The model improves resource utilization, reduces traffic loss and enhances survivability.

Publication : *SARMA, A. K., Deka, S. K., & Sarma. N. State-aware hybrid protection scheme considering splitting of demands in SEON based on heterogeneous traffic demands.(Ongoing).*

(14.1.4) We propose a fragmentation-aware spectrum allocation scheme for Elastic Optical Networks (EONs) to address dynamic traffic conditions where spectrum fragmentation significantly degrades network performance. We develop an Integer Linear Programming (ILP) approach that evaluates k-shortest paths between source-destination pairs and selects the path requiring minimal spectrum resources while minimizing fragmentation through coordinated routing and spectrum allocation. Our ILP formulation integrates path selection, modulation format selection, and spectrum allocation into a unified optimization that balances minimizing resource usage and fragmentation. To address computational complexity limitations in large networks, we also introduce a heuristic approach that focuses on boundary regions of available spectrum blocks rather than evaluating all possible combinations. Our numerical results on NSFNET and NKN topologies demonstrate that both proposed schemes outperform conventional allocation methods (first-fit, best-fit, last-fit, MinEnt RSA) by achieving significantly lower blocking probabilities and better resource utilization across different traffic loads and network configurations.

Publication: Duarah, P., Hussain Barbhuiya, D., Sarma, N., K. Deka, S., & Chand Chatterjee, B. (n.d.). *Fragmentation-Aware Spectrum Allocation for Dynamic Traffic in Elastic Optical Networks* (Accepted)

(14.1.7) We propose a fragmentation and crosstalk aware spectrum allocation scheme for Spectrally-Spatially Elastic Optical Networks (SS-EONs) under dynamic traffic scenarios. We develop an ILP formulation that presents a multi-dimensional optimization framework simultaneously addressing three traditionally decoupled objectives: connection blocking minimization, crosstalk interference mitigation, and spectrum fragmentation reduction using Pareto optimization techniques. To address computational complexity limitations in large networks, we also introduce a heuristic approach. Our numerical results on NSFNET, NKN, and USNET topologies demonstrate that both proposed schemes outperform existing resource

allocation methods by achieving significantly lower blocking probabilities, improved fairness index, and better resource utilization across different traffic loads and network configurations.

Publication: Fragmented and crosstalk aware resource allocation in SS-EON for dynamic traffic scenario (ongoing)

(14.1.14) In this work we proposed GATrans-DRL-RSA, a deep reinforcement learning framework that combines Graph Attention Networks (GAT) with Transformer architecture for routing, band, modulation, and spectrum allocation (RBMSA) in C+L band elastic optical networks. The work addresses critical challenges in multi-band EONs where traditional approaches suffer from limitations: fully connected neural networks extract limited features from non-Euclidean network topologies, graph convolutional networks experience over-smoothing that destroys topological information, and recurrent neural networks struggle with long-range dependencies and sequential processing bottlenecks. GATrans-DRL-RSA's key innovation lies in its integrated architecture where the GAT module intelligently learns dynamic inter-link relationships and spectrum dependencies across the fiber network, while the Transformer module employs dual attention mechanisms self-attention for modeling dependencies within candidate routing paths and cross-attention for integrating global network context from GAT with local path-specific characteristics. The framework features attention pooling to dynamically identify critical bottleneck links and dual-processing pipelines that separately handle C-band and L-band characteristics while considering physical layer impairments like inter-channel stimulated Raman scattering (ISRS) and Kerr effects. Simulations across NSFNET, Euro-28, and COST-239 networks demonstrate that GATrans-DRL-RSA achieves 54-66% blocking probability reduction compared to rule-based approaches and 8.3-46% improvement over existing DRL schemes, while maintaining exceptional generalization capabilities with less than 0.1% performance variation under ±25% traffic distribution shifts and delivering 44.2-64.4% traffic admissibility improvements, thus validating the effectiveness of attention-based machine learning for optimizing resource allocation in next-generation multi-band optical networks.

Publication: D. H. Barbhuiya, S. K. Deka, N. Sarma, S. Subramaniam and B. C. Chatterjee, "GATrans-DRL-RSA: Graph Attention
Network and Transformer-Based Deep Reinforcement Learning for Routing and Spectrum Allocation in C+L Band Elastic Optical Networks", IEEE Transactions on Networking, 2025 (under review)

(7.1.) (7.2) In this work we proposed Fragmentation-Aware Resource Allocation with Spectrum Partitioning (FARASP), a comprehensive scheme for managing spectrum fragmentation in Elastic Optical Networks (EONs) that addresses limitations of existing fragmentation metrics in partitioned spectrum scenarios. The key innovation is a dual optimization approach that tackles both path selection and spectrum block allocation to minimize fragmentation. FARASP introduces the Spectrum Alignment Ratio (SAR) metric, specifically designed to measure fragmentation in partitioned spectrum environments, which outperforms conventional metrics like SEnFM, EF, ABP, and CARSD that fail to accurately assess fragmentation when spectrum partitioning is used. The scheme operates in three phases: (1) Path selection using SAR to identify routes with best-aligned spectrum slots, (2) Spectrum block identification incorporating connection termination time awareness to synchronize connection release times and create well-aligned free blocks for future use, and (3) Connection establishment. We formulated Routing and Spectrum Allocation with Spectrum Partitioning (RSA-SP) problem as an integer linear programming optimization for

static scenarios and proved its decision version is NP-complete. Simulations across Euro-28, NSFNET, and NKN networks with four different traffic profiles demonstrate that FARASP significantly outperforms conventional schemes (SEnFM-RMSA, FMM-RMSA, and SDFA), achieving 44.5%, 45.3%, and 47.1% more traffic accommodation respectively at 1% blocking probability, while also providing substantial improvements in blocking probability reduction, spectrum utilization, and average path fragmentation across all network topologies and traffic conditions.

Publication: D. H. Barbhuiya, S. K. Deka, N. Sarma, and B. C. Chatterjee, "FARASP: Fragmentation-Aware Resource Allocation
with Spectrum Partitioning in Elastic Optical Networks", Computer Networks, Volume 269, 2025

(8.1.1) We proposed a bandwidth demand-grouping based fair spectrum-partitioning, and spectrum allocation scheme for elastic optical networks that addresses inefficiencies in traditional dedicated partitioning approaches. While conventional methods allocate separate, dedicated spectrum partitions for each bandwidth demand type leading to underutilized spectrum and higher blocking probabilities when sufficient slots exist in other partitions, our proposed scheme groups bandwidth demands based on slot requirements, allowing two demand types to share a common spectrum partition. The scheme employs an Integer Linear Programming (ILP) model to optimally group demands by maximizing the minimum diameter of groups while ensuring similar diameters and determines fair partition sizes based on occurrence probabilities of each demand type calculated using distance-adaptive modulation format selection. Within each shared partition, spectrum allocation is performed using the First-Last Fit (FLF) policy. Simulation results on NSFNET (14-node) and Cost-256 (28-node) networks demonstrate that DGSP significantly outperforms conventional dedicated partitioning schemes (DP-FF and DP-FLF), achieving remarkable blocking probability reductions of up to 97.51% for NSFNET and 56.09% for Cost-256 across varying traffic loads (100-300 Erlang), thereby proving the effectiveness of demand grouping in reducing spectrum wastage and improving network resource utilization efficiency.

Publication: D. H. Barbhuiya, S. K. Deka, N. Sarma, and B. C. Chatterjee, "POSTER: DGSP - Demand-Grouping and Spectrum-
Partitioning-Based Spectrum Allocation in Elastic Optical Networks," 2025 IEEE 26th International Conference
on High Performance Switching and Routing (HPSR), Suita, Osaka, Japan, 2025, pp. 1-3.

(6.2.1) We proposed a Machine Learning-Assisted Dynamic Spectrum Partitioning (ML-DSP), a scheme for EONs that addresses the inefficiencies of static spectrum partitioning approaches. The system uses an LSTM-based model to predict hourly traffic demands for each source-destination pair, then employs Integer Linear Programming (ILP) to dynamically optimize spectrum partition boundaries based on these predictions, with a heuristic algorithm provided for scalability. The approach divides time into intervals where, at each interval, the ML model forecasts future requests, ILP determines optimal partitions while ensuring fairness constraints, and connections are allocated using a First-Last Fit (FLF) policy. Experimental evaluation on 14-node Dutch Telecom and 24-node US networks demonstrates that ML-DSP significantly outperforms conventional static partitioning schemes, achieving 58% and 35% reductions in blocking ratios respectively, while also improving fairness in spectrum allocation across different demand types and enhancing overall spectrum time utilization, proving that machine learning-

driven dynamic partitioning can substantially improve network resource efficiency by adapting to predicted traffic patterns.

Publication: D. H. Barbhuiya, S. K. Deka, B. C. Chatterjee, and N. Sarma, "ML-DSP: Machine learning-assisted dynamic spectrum partitioning in elastic optical networks", in 2023 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS), 2023, pp. 108–113

IIIT Naya Raipur

(4.3.3) Modern communication networks rely on optical fiber networks to transmit various sensitive information among different organizations. With the evolution of fifth-generation telecom technologies, such as intelligent hyper-connected networks, the concentration of all transmission information on optical communication networks has become prevalent. Consequently, ensuring the security of optical transmission devices has become paramount. Establishing secure communication between optical access network nodes presents a significant challenge due to reported instances of hacking into optical cables, rendering the optical communication medium vulnerable to eavesdropping. Therefore, there is a pressing need for complementary security measures. This paper proposes a lightweight yet effective secure key distribution strategy to enhance the network security of optical communication. The proposed Key Exchange (KE) protocols, focusing on symmetric key sharing (SKS) and Secure Key Update (SKU), are subjected to Scyther-based security simulations to demonstrate their security. Additionally, an informal security analysis is provided to showcase the resilience of the SKS and SKU algorithms against various security attacks. Computational benchmarks show that both algorithms require fewer computational, communication, and storage resources during the key generation phase compared to related authentication protocols.

Publication: Amin, Ruhul. (2025). Lightweight Symmetric Key Exchange Protocols for Enhanced Security in Elastic Optical Fiber Communication. In: Giri, D., Islam, S.K.H., Vasilakos, A.V., Khan, M.K. (eds) Proceedings of International Conference on Network Security and Blockchain Technology. ICNSBT 2024. Lecture Notes in Networks and Systems, vol 1158. Springer, Singapore. https://doi.org/10.1007/978-981-97-8051-8_13

(5.1.1) Software-defined networking addresses traditional network issues by separating the data plane from the control plane, centralizing control in an SDN controller. The centralized approach allows the controller to manage all computational and complexity issues at the network level, rather than distributing these tasks among individual network elements. When applied to optical networks, the SDN architecture leverages the unique attributes of optical (photonic) communication components and their high transmission capacities, offering many applications. However, the SDN-based optical networks also face specific security challenges, including the need for secure data communication between entities to prevent unauthorized access and the importance of preserving entity privacy, among many others. Existing security protocols often depend on public-key cryptography, which relies heavily on computationally hard problems for security. Nevertheless, quantum adversaries can significantly reduce computational complexity, endangering existing protocols used for securing SDN-based optical network data exchange. In this research, we first present a quantum security architecture for SDN-based optical networks. Subsequently, we present a quantum-safe authentication mechanism (Q-AuthSDN) based on the quantum-security architecture. Q-AuthSDN employs a quantum-safe key distribution approach

and Hash functions. Furthermore, Q-AuthSDN's security features are evaluated against established requirements and performance is measured through simulations. Results show that Q-AuthSDN outperforms existing schemes in communication and computational overhead while demonstrating its suitability for real-world deployment.

Publication: Ruhul Amin, "Q-AuthSDN: Quantum-Safe Authentication Protocol with Key Management for Software Defined Optical Network", Transaction on Network and Service Management. Status: Under Review.

i) Scope : Development of Secured and Reliable Spectrum Allocation Schemes for Next-Generation Elastic Optical Networks with aim to reduce fragmentation and connection blocking probability issues considering NSFNET, EURO and NKN topology.

ii) No. of Systems/Sub-systems with specifications or feasibility report on futuristic studies : Algorithms and schemes developed will fit into the real network configurations in deployment while addressing the slot allocation constraints.

iii) No. of Research papers/Technical Reports: 12 (1 journal, 10 conf, 1 book chapter)

iv) No. of trained manpower: 3 (PhD Scholars), 2 (M. Tech), 3 (B. Tech)

v) Anticipated know-how transfer to industry: NIL

vi)Technology/Know-how developed (Hardware, software & other details, if any); Software Know-how document available or not: Available in the form of research paper publications, Project Report

vii) No. of industries shown interest for know-how utilization/commercialization: NIL

viii) No. of users/interested for taking prototype/ finished product. Optical Network research community

ix) No. of industries/users interested in applying the know-how developed for enhanced productivity: NIL

Additional information

i) Details of patents registered, if any : NIL

ii) Technological spin offs, seeding of a major activity and how the project has helped in enhancing the technological base/capabilities in the country :The project has contributed with RSA schemes and security protocols to enhance backbone network in India. The research works attributed to specially considering NKN network in India.

iii) Future areas for work : EON is evolving with multicore multiband based implementation, becoming smarter in resource management and allocation while considering different constraints in optical communication by adopting techniques of machine learning which will be left for future work. Furthermore, the technology shift is likely to happen soon by mean of quantum optical communication which will be interesting to work on in the future.

13/08/2025

Professor,
Dept. of Computer Science & Engg.
Tezpur University

Dr. Nityananda Sarma

Name & Signature of Chief Investigator

13/08/2025.

Signature of Head of the Institute/
Organisation with Office Stamp/Seal

Registrar I/C
Tezpur University
Napaam, Tezpur

Date:13-08-2025

TABLE 1 : HEADWISE BREAK-UP OF EXPENDITURE

(Rs. Lakhs)

S. No	Head	Approved Budget Outlay	Expenditure incurred Upto 31.03.24 RE FE Total	Expenditure from 1.04.24 to 30.04.25 RE FE Total	Anticipated expenditure from ---------to--- RE BE Total	BE Remarks
1	Capital Equipment (FE Comp)*	21.0	20.3361	Nil	NA	
2	Consumable items/components (FE Comp)	0.9	0.2999	0.2998	NA	
3	Duty on Imports	Nil	Nil	Nil	NA	
4	Staff Salaries	53.0784	25.65066	20.89978	NA	
5	Travel	4.5	0.7838	0.66424	NA	
6	Contingencies	0.9	0.35	0.30021	NA	
7	Overheads, if any	5.93784	2.52655	2.4725	NA	
8	Other expenditure debitable to this project (please specify)	Nil	Nil	Nil	NA	
TOTAL		86.31624	49.94701	24.63653	NA	

- FE utilised, over and above sanction made by DeitY, through OGL facilities may be indicated separately.
- Please indicate if there is any deviation from originally approved budget and whether necessary approval has been taken.

TABLE 1.1 : HEADWISE BREAK-UP OF EXPENDITURE (TEZPUR UNIVERSITY)

(Rs. Lakhs)

S. No	Head	Approved Budget Outlay	Expenditure incurred Upto 31.03.24 RE FE Total	Expenditure from 1.04.24 to 30.04.25 RE FE Total	Anticipated expenditure from ---------to--- RE BE Total	BE Remarks
1	Capital Equipment (FE Comp)*	6.0	5.3361	Nil	NA	
2	Consumable items/components (FE Comp)	0.3	0.1999	0.1	NA	
3	Duty on Imports	Nil	Nil	Nil	NA	
4	Staff Salaries	25.1424	15.17466	14.4243	NA	
5	Travel	1.5	Nil	0.26424	NA	
6	Contingencies	0.3	0.2	0.1	NA	
7	Overheads, if any	2.72424	0.95871	1.76171	NA	
8	Other expenditure debitable to this project (please specify)	Nil	Nil	Nil	NA	
TOTAL		35.96664	21.86837	16.65025	NA	

- FE utilised, over and above sanction made by DeitY, through OGL facilities may be indicated separately.
- Please indicate if there is any deviation from originally approved budget and whether necessary approval has been taken.

TABLE 1.2 : HEADWISE BREAK-UP OF EXPENDITURE (SOUTH ASIAN UNIVERSITY)

(Rs. Lakhs)

S. No	Head	Approved Budget Outlay	Expenditure incurred Upto 31.03.24 RE FE Total	Expenditure from 1.04.24 to 30.04.25 RE FE Total	Anticipated expenditure from ---------to--- RE BE Total	BE Remarks
1	Capital Equipment (FE Comp)*	11.0	11.0	Nil	NA	
2	Consumable items/components (FE Comp)	0.3	Nil	0.19980	NA	
3	Duty on Imports	Nil	Nil	Nil	NA	
4	Staff Salaries	14.4336	6.32607	6.47548	NA	
5	Travel	1.5	0.38380	0.4	NA	
6	Contingencies	0.3	Nil	0.20021	NA	
7	Overheads, if any	1.65336	0.94256	0.71079	NA	
8	Other expenditure debitable to this project (please specify)	Nil	Nil	Nil	NA	
TOTAL		29.18696	18.65243	7.98628	NA	

- FE utilised, over and above sanction made by DeitY, through OGL facilities may be indicated separately.
- Please indicate if there is any deviation from originally approved budget and whether necessary approval has been taken.

TABLE 1.3 : HEADWISE BREAK-UP OF EXPENDITURE (IIIT NAYA RAIPUR)

(Rs. Lakhs)

S. No	Head	Approved Budget Outlay	Expenditure incurred Upto 31.03.24 RE FE Total	Expenditure from 1.04.24 to 30.04.25 RE FE Total	Anticipated expenditure from ---------to---- RE BE Total	BE Remarks
1	Capital Equipment (FE Comp)*	4.0	4.0	Nil	NA	
2	Consumable items/components (FE Comp)	0.3	0.1	Nil	NA	
3	Duty on Imports	Nil	Nil	Nil	NA	
4	Staff Salaries	13.5024	4.14993	Nil	NA	
5	Travel	1.5	0.40	Nil	NA	
6	Contingencies	0.3	0.15	Nil	NA	
7	Overheads, if any	1.56024	0.62528	Nil	NA	
8	Other expenditure debitable to this project (please specify)	Nil	Nil	Nil	NA	
TOTAL		21.16264	9.42521	Nil	NA	

- FE utilised, over and above sanction made by DeitY, through OGL facilities may be indicated separately.
- Please indicate if there is any deviation from originally approved budget and whether necessary approval has been taken.

TABLE 2.1 EQUIPMENT (IMPORTED) PROCURED FOR THE PROJECT

(Rs. In Lakhs)

S.No	Description	Manufacturer/ Supplier	Brief Specifications	Purchase Order No. & date	Date of Receipt	Total Cost	Duty * Paid	Condition G-good B-bad
					TOTAL			

* Please indicate duty amount paid for each equipment

** Mention condition of equipment purchased. If bad, describe the fault/defect and what action has been taken to repair it?

TABLE 2.2 CAPITAL EQUIPMENT (INDIGENOUS) PROCURED FOR THE PROJECT

TEZPUR UNIVERSITY

(Rs. In Lakhs)

S.No	Description	Manufacturer/ Supplier	Brief Specifications	Purchase Order No. & date	Date of Receipt	Cost	Condition G-good B-bad
1	*Workstation (Qty: 1)*	*Dell/ WIMAX*	*Intel Xeon W-1250 (6 Core, 12M cache, base 3.3GHz, up to 4.7GHz), Windows® 10 Pro for Workstations (64 bit) w/ Intel Xeon processors*	*GEMC-5116877608 61474, Dated: 12/01/2022 TU/Fin/Proj /60-591/20/21-22/2476*	*16/03/2022*	*1,22,325/-*	G
2	*PC (Qty: 3)*	*Dell/ WIMAX*	*9th Generation Intel® Core™ i5 Processors, Windows 10 Pro 64bit, 8GB DDR4, Intel UHD Graphics*	*GEMC-5116877608 61474, Dated: 12/01/2022 TU/Fin/Proj /60-591/20/21-22/2476*	*16/03/2022*	*1,66,635/-*	G
3	*Laptop (Qty: 2)*	*Microsoft Surface/ WIMAX*	*Quad Core 11th Gen Intel® Core™ i7-1185G7 Processor, 8GB RAM, SSD 512GB HDD 10th Gen Intel® Core™ i5-1065G1 Processor, 8GB RAM, SSD 128GB HDD*	*GEMC-5116877608 61474, Dated: 12/01/2022 TU/Fin/Proj /60-591/20/21-22/2476*	*16/03/2022*	*2,03,700/-*	G
4	*Printer & Scanner (Qty: 1)*	*HP/ WIMAX*	*HP LaserJet Multifunction Printer*	*GEMC-5116877608 61474, Dated: 12/01/2022 TU/Fin/Proj /60-591/20/21-22/2476*	*16/03/2022*	*40,950/-*	G
					Total	**5,33,610**	

* Mention condition of equipment purchased. If bad, describe the fault/defect and what action has been taken to repair it?

TABLE 2.2 CAPITAL EQUIPMENT (INDIGENOUS) PROCURED FOR THE PROJECT

IIIT NAYA RAIPUR

(Rs. In Lakhs)

S.No	Description	Manufacturer/ Supplier	Brief Specifications	Purchase Order No. & date	Date of Receipt	Cost	Condition G-good B-bad
1	Printer & Scanner(Qty: 1)	HP	Hp Multifunction Machine mfm, on site OEM Warranty 1 year hp, hp color laserjet pro MFP M183FW with 1 year warranty	GEMC-5116877278 23230 12 OCR, 21	1/11/2021	46,500/-	G
2	Workstation (Qty: 1)	Apple	Apple AIO/M1 chip/24 inch/256gb SSD/8GB RAM	BC/2122/JN -00318	8/11/2021	1,36,500/-	G
3	Laptop (01)	HP	HP laptop 17/11th/8GB RAM/512 GB SSD/W10 home/MS office	DTS/97/202 1-22	17/03/2022	85,000/-	G
4	Dell Laptop 7420 (01)	Dell	Dell laptop/Intel-i5-1135G7/8GB/DD R4,512GB SSD etc.	2164/JW	08.11.2022	95,000/-	G
5	Tablet 10 Inch,	Lenovo	Tablet 10 Inch, Make: Lenovo, Model M10, RAM-4GB, S/N-HA1GYQ5T	GE/22-23/02	20.04.2022	24,800/-	G
6	Seagate Backup (HDD)	Seagate	Seagate backup plus 5TB	2165/JW	08.11.2022	12,000/-	G
					Total	**3,99,800**	

* Mention condition of equipment purchased. If bad, describe the fault/defect and what action has been taken to repair it?

TABLE 2.3 SALE/TRANSFER OF CAPITAL GOODS (WITH PRIOR PERMISSION OF DeitY)

S.No.	Description	Sale/Transfer S/T	Orgn. To which sold/ Transferred	Sale Value Rs. In lakhs	Funds Refunded to DeitY

TABLE 3: MANPOWER ASSOCIATED WITH THE PROJECT* :

* (a) Institute Faculty and staff

S.No	Name	Designation	Qualification	% of time devoted to this project	Salary drawn Y/N	Date of Joining	Date of Leaving	Total average emoluments (monthly)
Tezpur University, Assam								
1	Prof. Nityananda Sarma	Professor, CSE, Tezpur University	PhD	20%	N	NA	NA	PI
2	Prof. Sanjib K. Deka	Professor, CSE, Tezpur University	PhD	30%	N	NA	NA	Co-PI
3	Amit Khanjan Sharma	JRF	MTech	100%	Y	09-November-2021	10-March-2025	31,000/- (up to Dec 2022) 37,000/- (up to 8-Nov, 2023) 42,000/- (till 10-Mar-2025)
4	Pinkey Duarah	JRF	MTech	100%	Y	09-November-2021	10-March-2025	31,000/- (2021-2022) 37,000/- (up to 8-Nov, 2023) 42,000/- (till 10-Mar-2025)
South Asian University, New Delhi								
5	Dr. Bijoy Chan. Chatterjee	Assoc. Professor, SAU, New Delhi	PhD	30%	N	NA	NA	PI
6	Akbar Ali	JRF	MTech	100%	Y	24-January-2022	3-March-2022	31,000/-
7	Dilwar Hussain Barbhyuan	JRF	MTech	100%	Y	7-June-2022	10-March-2025	31,000/- (up to Dec 2022) 37,000/- (up to 6-June, 2024) 42,000/- (till 10-Mar-2025)
IIIT Naya Raipur, Chhattisgarh								
8	Dr. Ruhul Amin	Assistant Professor, IIIT Naya Raipur	PhD	30%	N	NA	NA	PI
9	Sudipta Sikdar	JRF	MTech	100%	Y	18-November-2021	October-2022	31,000/-
10	Pradyumn Pandey	JRF	MCA	100%	Y	21-December-2022	31-May-2023	31,000/-

(b) Staff recruited for the project

(c) Students

FORM G.P.R. 19

(SEE GOVERNMENT OF INDIA'S DECISION 7(B) UNDER RULE 148 (3)
Assets Acquired wholly or substantially out of Government grants
Register maintained by grantee institution

Block Account maintained by Sanctioning Authorities

Name of Sanctioning Authority .....

Name of Grantee Institution	No. & Date of sanction	Amount of the sanctioned grant	Brief purpose of the grant	Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid sanction	Particulars of assets actually credited or acquired	Value of the assets as on	Purpose for which utilised at present	Encumber-ed or not	Reasons if encumber--ed	Disposed off or note	Reasons & authority, if any, for disposal	Amount realised on	Remarks
Ministry of Electronics and Information Technology (MeitY)	No. 13(34)/2020-CC&BT, Dated 11.03.2021	Rs. 86.31624 lakhs	Implementation of Research Project	No	As per Table 2	Same as in Table 2	Research Work	No	N/A	No	N/A	N/A	Nil

Form GFR 19 - A

Form of Utilisation Certificate

S.No.	Letter No.	Amount	Certified that out of **Rs. 40,48,374** of Grants-in-aid sanctioned during the Year 2021-2026 in favour of **Tezpur University** under this Ministry /Department Letter no. given in the margin and Rs. **Nil** on account of unspent balance of the previous year, a sum of **Rs. 38,51,962** has been utilised for the purpose of for which it was sanctioned and that the balance of **Rs 1,96,412** remaining unutilised at the end of the year 2023 and 2025 has been surrendered to Government (vide UTR: SBIN222336231816, dtd. 02.12.2022, via CNA to RBI A/C: 10679401002 (TSA-2354), dtd. 28.03.2025) / ~~will be adjusted towards the grants-in-aid payable during the next year~~.
1.	13(34)/2020-CC&BT dtd. 11.03.2021	Rs.15,49,872	
2.	13(34)/2020-CC&BT dtd. 09.10.2023	Rs. 8,19,901	
3.	13(34)/2020-CC&BT dtd. 29.07.2024	Rs.11,75,505	
4.	13(34)/2020-CC&BT dtd. 29.04.2025	Rs. 5,03,096	
	Total:	**Rs. 40,48,374**	

2. Certified that I have satisfied myself that the conditions on which the grants-in-aid was sanctioned have been duly fulfilled/are being fulfilled and that I have exercised the following checks to see that the money was actually utilised for the purpose for which it was sanctioned.

Kinds of checks exercised.

1. Tezpur University Accounts are Audited by the CAG every year
2. Government rules are followed in procurement of equipment
3. Standard procedures and the Tezpur University rules have been followed in recruiting the project staff

13.08.2025
Dr. Nityananda Sarma
Professor,
Dept. of Computer Science & Engg.
Tezpur University

GFR 12 – A

[(See Rule 238 (1)]

FORM OF UTILIZATION CERTIFICATE FOR AUTONOMOUS BODIES OF THE GRANTEE ORGANIZATION

UTILIZATION CERTIFICATE FOR THE YEAR **2021 - 2022** in respect of recurring/non-recurring GRANTS-IN-AID/SALARIES/CREATION OF CAPITAL ASSETS

1. Name of the Scheme.....**R & D in CC&BT**.....
2. Whether recurring or non-recurring grants.....**Non-recurring**
3. Grants position at the beginning of the Financial year
   (i) Cash in Hand/Bank: Nil
   (ii) Unadjusted advances: Nil
   (iii) Total: **Nil**
4. Details of grants received, expenditure incurred and closing balances: (Actuals)

Unspent Balances of Grants received years [figure as at Sl. No. 3 (iii)]	Interest Earned thereon	Interest deposited back to the Govern-ment	Grant received during the year			Total Available funds (1+2-3+4)	Expenditure incurred	Closing Balances (5-6)
1	2	3	4			5	6	7
			Sanction No. (i)	Date (ii)	Amount (iii)			
0	62,494	**62,494***	13(34)/ 2020-CC&BT	11.03. 2021	41,63,952	41,63,952	14,22,389	27,41,563

Component wise utilization of grants:

Grant-in-aid– General	Grant-in-aid– Salary	Grant-in-aid–creation of capital assets	Total
14,22,389			14,22,389

Details of grants position at the end of the year

(i) Cash in Hand/Bank: Rs. 27,41,563/-

(ii) Unadjusted Advances: Nil

(iii) Total: **Rs. 27,41,563/-**

* **Rs. 62,494/-** has been deposited vide UTR Nos. (Rs.16,971/- UTR No. SBIN422245999545 dtd. 02/09/2022, Rs. 30,016/- UTR No. SBIN322272036918 dtd. 29/09/2022, Rs. 15,507/- UTR No. UBINJ22252662388 dtd. 09/09/2022)

Professor

GENERAL FINANCIAL RULES 2017
Ministry of Finance
Department of Expenditure

FORM GFR 12A

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under..... (name of the scheme has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given at Annexure – I duly enclosed.

(viii) The utilization of the fund resulted in outcomes given at Annexure – II duly enclosed (to be formulated by the Ministry/Department concerned as per their requirements/specifications.)

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed at Annexure –II (to be formulated by the Ministry/Department concerned as per their requirements/specifications).

Date:

Place:

Signature

Name CMA Dr. Braja Bandhu Mishra

Chief Finance Officer

(Head of the Finance)

Finance Officer
Tezpur University

Signature

Name Dr. Biren Das

Head of the Organisation

Registrar
Tezpur University

(Strike out inapplicable terms)

30.11.2022

GFR 12 – A

[(See Rule 238 (1)]

FORM OF UTILIZATION CERTIFICATE FOR AUTONOMOUS BODIES OF THE GRANTEE ORGANIZATION

UTILIZATION CERTIFICATE FOR THE YEAR **April' 2022-November' 2022** in respect of recurring/non-recurring GRANTS-IN-AID/SALARIES/CREATION OF CAPITAL ASSETS

1. Name of the Scheme.....**R & D in CC&BT**.....
2. Whether recurring or non-recurring grants.....**Non-recurring**
3. Grants position at the beginning of the Financial year : **2022-2023**
   (i) Cash in Hand/Bank: **27,41,563.00**
   (ii) Unadjusted advances: Nil
   (iii) Total: **27,41,563.00**
4. Details of grants received, expenditure incurred and closing balances: (Actuals)

Unspent Balances of Grants received years [figure as at Sl. No. 3 (iii)]	Interest Earned thereon	Interest deposited back to the Govern-ment	Grant received during the year			Total Available funds (1+2-3+4)	Expenditure incurred	Closing Balances (5-6)
1	2	3	4			5	6	7
			Sanction No. (i)	Date (ii)	Amount (iii)			
27,41,563	27,688	**6,40,104***	13(34)/ 2020-CC&BT	11.03. 2021	Nil	21,29,147	21,29,147	**0**

Component wise utilization of grants:

Grant-in-aid– General	Grant-in-aid– Salary	Grant-in-aid–creation of capital assets	Total
21,29,147			21,29,147

Details of grants position at the end of the year

(i) Cash in Hand/Bank: Nil

(ii) Unadjusted Advances: Nil

(iii) Total: **Nil**

* **Rs. 6,40,104/-** which includes interest earned of **Rs. 27,688/-** in **FY 2022-2023** shown in col. 3 of the sl. No. 4 has been transferred to MeitY (UTR No.: **SBIN222336231816** dtd. **02.12.2022**)

GENERAL FINANCIAL RULES 2017
Ministry of Finance
Department of Expenditure

FORM GFR 12A

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under..... (name of the scheme has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given at Annexure – I duly enclosed.

(viii) The utilization of the fund resulted in outcomes given at Annexure – II duly enclosed (to be formulated by the Ministry/Department concerned as per their requirements/specifications.)

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed at Annexure –II (to be formulated by the Ministry/Department concerned as per their requirements/specifications).

Date:

Place:

Signature

Name CMA Dr. Braja Bandhu Mishra

Chief Finance Officer

(Head of the Finance)

Finance Officer
Tezpur University

Signature

Name Dr. Biren Das

Head of the Organisation

Registrar
Tezpur University

(Strike out inapplicable terms)

30.11.2022

FORM GFR 12A

GENERAL FINANCIAL RULES 2017
Ministry of Finance
Department of Expenditure

GFR 12 – A

[(See Rule 238 (1)]

FORM OF UTILIZATION CERTIFICATE FOR AUTONOMOUS BODIES OF THE GRANTEE ORGANIZATION

UTILIZATION CERTIFICATE FOR THE YEAR **April' 2023-March' 2024** in respect of recurring/non-recurring
GRANTS-IN-AID/SALARIES/CREATION OF CAPITAL ASSETS

1. Name of the Scheme.....**R & D in CC&BT**.....
2. Whether recurring or non-recurring grants.....**Non-recurring**
3. Grants position at the beginning of the Financial year : **2023-2024**
   (i) Cash in Hand/Bank: **Nil**
   (ii) Unadjusted advances: **Nil**
   (iii) Total: **Nil**
4. Details of grants received, expenditure incurred and closing balances: (Actuals)

Unspent Balances of Grants received years [figure as at Sl. No. 3 (iii)]	Interest Earned thereon	Interest and amount deposited back to the Govern-ment	Grant received during the year			Total Available funds (1+2-3+4)	Expenditure incurred	Closing Balances (5-6)
1	2	3	4			5	6	7
			Sanction No. (i)	Date (ii)	Amount (iii)			
Nil	**Nil**	**Nil**	**13(34) /2020-CC&BT**	**09.10 .2023**	**8,19,901**	**8,19,901**	**8,19,901**	**Nil**

Component wise utilization of grants:

Grant-in-aid–General	Grant-in-aid–Salary	Grant-in-aid–creation of capital assets	Total
8,19,901			**8,19,901**

Details of grants position at the end of the year
(i) Cash in Hand/Bank: **Nil**
(ii) Unadjusted Advances: **Nil**
(iii) Total: **Nil**

Dr. Nityananda Sarma (PI)
Professor,
Department of Computer Science & Engg.
Tezpur University

GENERAL FINANCIAL RULES 2017
Ministry of Finance
Department of Expenditure

FORM GFR 12A

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under **R & D in CC&BT** (name of the scheme has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given at Annexure – I duly enclosed.

(viii) The utilization of the fund resulted in outcomes given at Annexure – II duly enclosed (to be formulated by the Ministry/Department concerned as per their requirements/specifications.)

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed at Annexure –II (to be formulated by the Ministry/Department concerned as per their requirements/specifications).

Date: **04-03-2024**

Place: **Tezpur**

Signature

Name CMA Dr. Braja Bandhu Mishra

Chief Finance Officer

(Head of the Finance)

Finance Officer
Tezpur University

Signature

Name Dr. Bizen Das

Head of the Organisation

Registrar
Tezpur University

(Strike out inapplicable terms)

Sarma.
Dr Nityananda Sarma (PI)

Professor,
Department of Computer Science & Engg.
Tezpur University

GFR 12 – A

[(See Rule 238 (1)]

FORM OF UTILIZATION CERTIFICATE FOR AUTONOMOUS BODIES OF THE GRANTEE ORGANIZATION

UTILIZATION CERTIFICATE FOR THE YEAR **April' 2024-March' 2025** in respect of recurring/non-recurring
GRANTS-IN-AID/SALARIES/CREATION OF CAPITAL ASSETS

1. Name of the Scheme.....**R & D in CC&BT**.....
2. Whether recurring or non-recurring grants.....**Recurring**.....
3. Grants position at the beginning of the Financial year: **2024-2025**
   (i) Cash in Hand/Bank: **0**
   (ii) Unadjusted advances: Nil
   (iii) Total: **0**
4. Details of grants received, expenditure incurred and closing balances: (Actuals)

Unspent Balances of Grants received years [figure as at Sl. No. 3 (iii)]	Interest Earned thereon	Unspent amount deposited back to the Govern-ment	Grant received during the year			Total Available funds (1+2-3+4)	Expenditure incurred	Closing Balances (5-6)
1	2	3	4			5	6	7
			Sanction No. (i)	Date (ii)	Amount (iii)			
Nil	Nil	**13,576 ***	13(34)/ 2020-CC&BT	29.07. 2024	**11,75,505**	**11,61,929**	**11,61,929**	**0**

Component wise utilization of grants:

Grant-in-aid–General	Grant-in-aid–Salary	Grant-in-aid–creation of capital assets	Total
2,22,595	9,39,334		**11,61,929**

Details of grants position at the end of the year

(i) Cash in Hand/Bank: **Nil**

(ii) Unadjusted Advances: **Nil**

(iii) Total: **Nil**

***Rs. 13,576 returned to MeitY on 28.03.2025 via CNA to RBI A/C: 10679401002 (TSA-2354), IFSC: RBIS0PFMS01 from A/C No: 10687701102 (Tezpur University)**

14.5.25
Professor,
Department of Computer Science & Engg
Tezpur University

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

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(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under **R & D in CC&BT** (name of the scheme has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given at Annexure – I duly enclosed.

(viii) The utilization of the fund resulted in outcomes given at Annexure – II duly enclosed (to be formulated by the Ministry/Department concerned as per their requirements/specifications.)

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed at Annexure –II (to be formulated by the Ministry/Department concerned as per their requirements/specifications).

Date: **14.05.2025**

Place: **Tezpur**

Signature 15/5/2025

Name: **CMA Dr. Braja Bandhu Mishra**

Chief Finance Officer

(Head of the Finance) Finance Officer
Tezpur University

Signature 15/05/25

Name: **Prof. Kailash Chandra Biswal**

Head of the Organisation

Registrar
Tezpur University

14.5.25
Professor,
Department of Computer Science & Engg
Tezpur University

GFR 12 – A

[(See Rule 238 (1)]

FORM OF UTILIZATION CERTIFICATE FOR AUTONOMOUS BODIES OF THE GRANTEE ORGANIZATION

UTILIZATION CERTIFICATE FOR THE YEAR **April 2025 to June' 2025** in respect of recurring/non-recurring GRANTS-IN-AID/SALARIES/CREATION OF CAPITAL ASSETS

1. Name of the Scheme.....**R & D in CC&BT**.....
2. Whether recurring or non-recurring grants.....**Recurring**.....
3. Grants position at the beginning of the Financial year: **2025-2026**
   (i) Cash in Hand/Bank: **0**
   (ii) Unadjusted advances: Nil
   (iii) Total: **0**
4. Details of grants received, expenditure incurred and closing balances: (Actuals)

Unspent Balances of Grants received years [figure as at Sl. No. 3 (iii)]	Interest Earned thereon	Interest/Unspent amount deposited back to the Govern-ment	Grant received during the year			Total Available funds (1+2-3+4)	Expenditure incurred	Closing Balances (5-6)
1	2	3	4			5	6	7
			Sanction No. (i)	Date (ii)	Amount (iii)			
Nil	Nil	Nil	13(34)/ 2020-CC&BT	29.04. 2025	**5,03,096**	**5,03,096**	**5,03,096**	**0**

Component wise utilization of grants:

Grant-in-aid–General	Grant-in-aid–Salary	Grant-in-aid–creation of capital assets	Total
	5,03,096		**5,03,096**

Details of grants position at the end of the year

(i) Cash in Hand/Bank: **Nil**

(ii) Unadjusted Advances: **Nil**

(iii) Total: **Nil**

11.8.2025
Professor,
Dept. of Computer Science & Engg.
Tezpur University

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

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(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under **R & D in CC&BT** (name of the scheme has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given at Annexure – I duly enclosed.

(viii) The utilization of the fund resulted in outcomes given at Annexure – II duly enclosed (to be formulated by the Ministry/Department concerned as per their requirements/specifications.)

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed at Annexure –II (to be formulated by the Ministry/Department concerned as per their requirements/specifications).

Date: **11.08.2025**

Place: **Tezpur**

Signature 21/8/25

Name: **CMA Dr. Braja Bandhu Mishra**

Chief Finance Officer

(Head of the Finance) Finance Officer
Tezpur University

Signature 22/08/2025

Name: **Prof. Pritam Deb**

Head of the Organisation

Registrar
Tezpur University

11.08.2025
Professor
Dept. of Computer Science & Engg.
Tezpur University

Development of Secured and Reliable Spectrum Allocation Schemes for Next-Generation Elastic Optical Networks

Statement of Expenditure

11.03.2021 to 30.04.2025

MeitY: 13(34)/2020-CC&BT dtd: 11-03-2021

Head	Approved Budget Outlay	After Reallocation in Budget Outlay from IIITNR	Grant Received (First installment in FY 2021-2022) (A)	Grant Received (Second installment in FY 2023-2024) (B)	Grant Received (Third installment in FY 2024-2025) (C)	Grant Received (Forth installment in FY 2025-2026) (D)	Total Grant Received (A+B+C+D) (E)	Expenditure Incurred					Total Expenditure	Balance till 01.05.2025 (L)	Remarks (if any)
								1st yr (11-Mar 2021 to 31-Mar-2022) (F)	2nd yr (1-Apr-2022 to 31-Mar-2023) (G)	3rd yr (1-Apr-2023 to 10-Mar-2024) (H)	4th yr (1-Apr-2024 to 10-Mar-2025) (I)	5th yr (11-Mar-2025 to 30th April 2025) (J)	(E + F + G + H + I) (K)		
Non - Recurring															
Capital Equipment	6,00,000	6,00,000	6,00,000	0	0	0	6,00,000	5,33,610	0	0	0	0	5,33,610	0	
Recurring															
Manpower	25,14,240	27,83,114	8,03,520	7,90,000	9,39,334	5,03,096	30,35,950	2,31,466	4,96,000	7,90,000	9,39,334	5,03,096	29,59,896	0	
Consumables	30,000	30,000	10,000	10,000	10,000	0	30,000	9,990	0	10,000	10,000	0	29,990	0	
Travel &Training	1,50,000	1,50,000	40,000	0	40,000	0	80,000	0	0	0	26,424	0	26,424	0	
Contingencies	30,000	30,000	10,000	10,000	10,000	0	30,000	10,000	0	10,000	10,000	0	30,000	0	
Overheads	2,72,424	2,72,424	86,352	9,901	1,76,171	0	2,72,424	85,970	0	9,901	1,76,171	0	2,72,042	0	
Total	35,96,664	38,65,538	15,49,872	8,19,901	11,75,505	5,03,096	40,48,374	8,71,036	4,96,000	8,19,901	11,61,929	0	**38,51,962**	0	
Refunded Amount	NA	NA	1,82,836 refunded to MeitY (UTR: SBIN2223362318 16, dtd. 02.12.2022)	Nil	Rs. 13,576 returned to MeitY on 28.03.2025 via CNA to RBI A/C. 10679401002 (TSA-2354)	Nil									
Total (After remitting the balance)	NA	NA	13,67,036	8,19,901	11,61,929	5,03,096	**38,51,962**	NA	NA	NA	NA		NA	NA	

* Interest Earned (2021-2022) = Total: Rs. 62,494 (TU: Rs. 16,971, SAU: Rs.30,016, IIIT NR:Rs.15,507) (Remitted) UTR: SBIN422245999545, dtd. 02.09.2022, UTR: SBIN322272036918, dtd. 29.09.2022, UTR: UBINJ22252662388, dtd. 09.09.2022

* Interest Earned (2022-2023) = Total: Rs. 27,688 (TU: Rs.2,868, SAU:Rs.18,667, IIIT NR:Rs.6,153) (Remitted) UTR: SBIN222336231816, dtd. 02.12.2022

* Balance Remaining (2022-2023) = Total: Rs.6,12,416 (TU:Rs.1,82,836, SAU:Rs. 2,84,293, IIIT NR:Rs.1,45,287) (Remitted) UTR: SBIN222336231816, dtd. 02.12.2022

* Balance Remaining (2024-2025) = Total: Rs.13,576 (Tezpur University) (Remitted) via CNA to RBI A/C: 10679401002 (TSA-2354), dtd. 28.03.2025, IFSC: RBISOPFMS01 from A/C No: 10687701102 (TU)

11.8.2025

Professor, Department of Computer Science & Engg. Tezpur University

Signature of the PI
Name: Dr. Nityananda Sarma
Date: 11/08/2025
Date of Start of Project: 11.03.2021
Department of Computer Science and Engineering
TEZPUR UNIVERSITY, NAPAAM, ASSAM

Signature of Competent Financial Authority
(With Seal and Date)

Finance Officer
Tezpur University