

# Deepak Choudhary Lalith

Research Assistant, Indian Institute of Science

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**Research Interests:** Computer Networking, Systems, Network Security, Tactile Internet, and Cyber-Physical Systems.

## Education

**REVA University, Bangalore** 2017 - 2021  
B.Tech, Electronics and Communication Engineering  
GPA: **9.10/10**, top 5% of the class

## Research Experience

**Indian Institute of Science (IISc) | Centre for Networked Intelligence** [🌐] Feb 2022 - Present  
*Research Assistant* | Advisors: [Dr. T. V. Prabhakar](#) and [Dr. Chandramani Singh](#)  
Projects: Time-Sensitive Networking (TSN), Tactile Cyber-Physical Systems (TCPS)

**REVA University, Bangalore** 2019 - 2021  
*Undergraduate Research Assistant* | Advisors: [Dr. Mrinal Sarvagya](#) and [Dr. Manjunath Kounte](#)  
Projects: Reversible Gates using Quantum-dot Cellular Automata (QCA)

**Indian Institute of Science (IISc), Bangalore** Fall 2020  
*Research Intern* | Advisor: [Dr. Anandi Giridharan](#)  
Project: Quantum Computing and Quantum Key Distribution (QKD) Algorithms on IBM's Qiskit framework

## Publications

**Towards a TSN-DetNet Intercity Testbed for Tactile Cyber-Physical Systems**  
Joydeep Pal, **Deepak Choudhary\***, Nithish Gnani\*, T.V.Prabhakar, Chandramani Singh, Hari Krishna Atluri, A. Paventhan  
*Accepted at IEEE International Conference on Computer Communications Workshops (INFOCOM) 2024* [IEEE INFOCOM '24]

**EdgeP4: In-Network Edge Intelligence for a Tactile Cyber-Physical System Testbed Across Cities** [🌐]  
Nithish Gnani, Joydeep Pal, **Deepak Choudhary**, Himanshu Verma, Soumya Rana, Kaushal Mhapsekar, T.V.Prabhakar, Chandramani Singh  
*Accepted at IEEE International Conference on Computer Communications Workshops (INFOCOM) 2024* [IEEE INFOCOM '24]

**DIA: Tactile Internet at a distance**  
H.J.C. Kroep, **Deepak Choudhary**, R.R.Venkatesha Prasad, T.V.Prabhakar  
*Under Submission*

**$\mu$ TAS: Design and implementation of Time Aware Shaper on SmartNICs to achieve bounded latency** [🌐]  
Joydeep Pal, **Deepak Choudhary**, Nithish Gnani, Chandramani Singh, T.V.Prabhakar  
*Under Submission* [arXiv pre-print]

**Enhancing Reliability of Scheduled Traffic in Time-Sensitive Networks using Frame Replication and Elimination** [🌐]  
Soumya Kanta Rana, Himanshu Verma, Joydeep Pal, **Deepak Choudhary**, T.V.Prabhakar, Chandramani Singh  
*IEEE International Symposium on Local and Metropolitan Area Networks* [IEEE LANMAN '23]

**LoRaWAN-Based Communication Protocol for Wearable Safety Devices in Mining Fields** [🌐]  
Namratha Karanth, **Deepak Choudhary**, Jaideep Francis Reddy, Ubay Athulla  
*Springer Lecture Notes in Electrical Engineering (LNEE)* [Springer LNEE '21]

## Teaching Responsibilities

**Teaching Assistant, TCP/IP Networking** *Indian Institute of Science* Fall 2023  
> A graduate TCP/IP Networking core course offered at DESE, IISc by Prof. T. V. Prabhakar and Prof. Joy Kuri.  
> Responsibilities include designing lab exercises every week, grading assignments, and resolving student doubts.

**Instructor** *NSE TalentSprint 5G Cohort* March '23, November '23  
> Conducted a hands-on workshop to teach data-plane programming using P4 under the guidance of Prof. T. V. Prabhakar.  
> Responsibilities included setting up a P4-programming environment using Mininet, providing in-depth explanations of programmable switch architecture, creating custom protocols and topology, and solving P4 exercises.

## Selected Research Projects

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- $\mu$ TAS: Achieving bounded latency for time-sensitive applications** 2022 - Present
- > Implemented a time-slotted scheduling mechanism on programmable smartNICs.
  - > Achieved bounded latency of 20  $\mu$ s for the scheduled traffic (ST) in the presence of best effort (BE) traffic.
  - > Demonstrated the algorithm across a physical testbed of two end-hosts connected via two switches.
  - > The bounded latency is **20x** lower compared to the Linux kernel-based implementation of Time Aware Shaper (TAS).

- EdgeP4: A P4-Programmable Edge Intelligent Ethernet Switch for TCPS** 2023
- Built a TCPS testbed to demonstrate teleoperation for real-time interaction between humans and robots.
- > Developed and implemented edge intelligence algorithms for teleoperation, pose correction, and tremor suppression on a P4-programmable edge switch.
  - > Reduces control loop latency (<100  $\mu$ s for pose correction task) and network load (up to 99% reduction).
  - > Developed pose correction algorithm to automatically adjust the pose of a robot while gripping a tool for real-time precision control.
  - > Developed a tremor-suppression algorithm on the edge switch that suppresses tremors in the robot arm while controlling it using a haptic device.

- Exploring Data-Plane Time Synchronization strategies** 2022 - Present
- > Implemented Precision Time Protocol (PTP) on a TSN testbed that achieved an average synchronization offset of 54 ns.
  - > Investigating the utilization of data-plane clocks to facilitate synchronization among programmable smartNICs/switches and equip them with IEEE 1588 transparent clock capabilities.
  - > Performed extensive measurements to characterize latency in the data plane and Linux Kernel.

- DIA: Tactile Internet at a distance** June '23 - November '23
- In collaboration with TU Delft. Advisors: T. V. Prabhakar, RR Venkatesha Prasad
- > Enabled intercontinental teleoperation of a robotic arm using a haptic device with haptic feedback over the internet.
  - > Initiated large-scale network measurements to characterize jitter, latency, and network paths to understand their effects on the operator's experience.

- Frame Replication and Elimination - to enhance reliability in TSN** August '22 - May '23
- > Developed packet de-duplication algorithms for SmartNICs to efficiently eliminate duplicates for enhancing the reliability of Scheduled Traffic.
  - > For duplicating over two links with 10% packet losses in each, achieved perfect de-duplication for a single 2.5 Gbps stream.
  - > For 12 simultaneous streams of total 1 Gbps, obtained de-duplication efficiency of 99.88% with 99.83% packet delivery.
  - > Work published at **IEEE LANMAN 2023**.

- P4-Netronome Workflow Setup & Testing** 2022
- > Carried out the hardware, software, and network topology setup from scratch to compile, deploy, and test P4 programs on Netronome SmartNIC.
  - > Established a network topology of workstations equipped with Netronome SmartNICs to successfully test the In-Band Network Telemetry (INT) and custom-scheduling P4 programs.
  - > Automated the compilation and testing of P4 programs with Python and bash scripts.
  - > Performed extensive latency measurements with the topology to design deterministic scheduling algorithms.

## Talks and Presentations

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### “[Demo] Designing Tactile Cyber-Physical Systems”

- > ITU Workshop May 2023 (IISc)
- > IISc Open Day March 2023 (IISc)
- > 6th Annual Symposium on Cyber-Physical Systems (CyPhySS) July 2022 (IISc)
- > Digital India Week July 2022 (Gandhinagar, Gujarat)

### “Achieving Bounded latency for Time-Sensitive Applications”

- > Cisco-IISc Day November 2022 (IISc)
- > IBM-IISc Research Day [📄] September 2022 (IISc)