# Evaluating TCP vs. UDP in Centralized Multi-Robot Communication using Star Topology

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# Introduction

- Multi-Robot Systems (MRS) enable teamwork and coordination between autonomous robots.
- Widely applied in automation, rescue operations, surveillance, and warehouse logistics.
- A centralized star topology simplifies control, since the hub manages all robot communications.
- However, this structure introduces a single point of failure at the hub.
- **Transmission Control Protocol (TCP):** reliable communication with acknowledgements and retransmissions, but slower due to overhead.
- **User Datagram Protocol (UDP):** faster and lightweight, but less reliable because of possible packet loss.
- **Aim of the study:** To evaluate which protocol is more suitable for different robotic communication tasks.

# Literature Survey

- Past studies have used platforms such as ROS, NS-2, and IoT-based setups, but these are not lightweight or MATLAB-based.
- Many works did not consider realistic network challenges such as packet loss, delay, and congestion.
- AI-based swarm control approaches have been proposed, but they require high computational resources and have not been validated in real-world conditions.
- **Identified Gap:** There is a need for a simple and customizable simulation framework that can evaluate communication protocols under identical conditions while incorporating realistic network faults.

# Objective

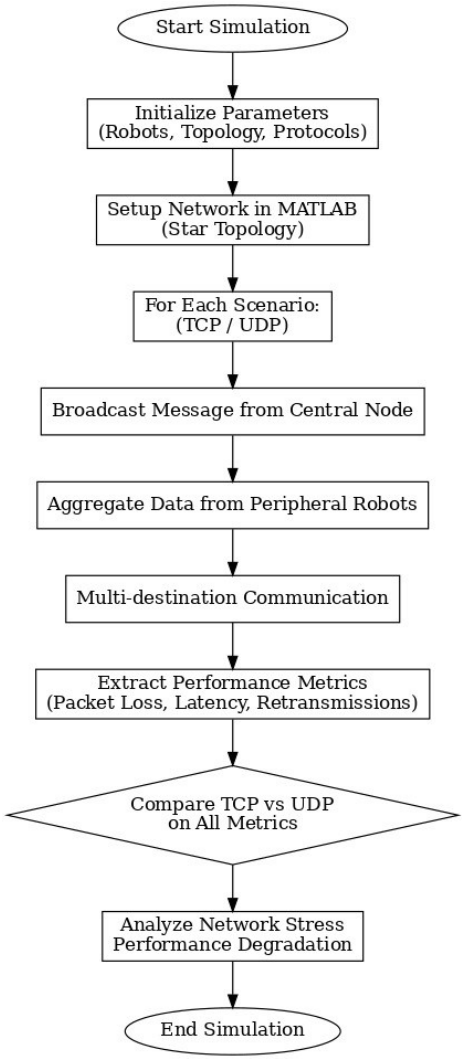
- Compare TCP vs UDP in a centralized six-robot star network.
- Create a MATLAB simulation to test both protocols.
- **Evaluate using**:
  - Latency (speed)
  - Packet Delivery Ratio (PDR) (reliability)
  - Retransmissions (overhead)
  - Throughput (data flow)
- Test five real-world inspired communication scenarios.

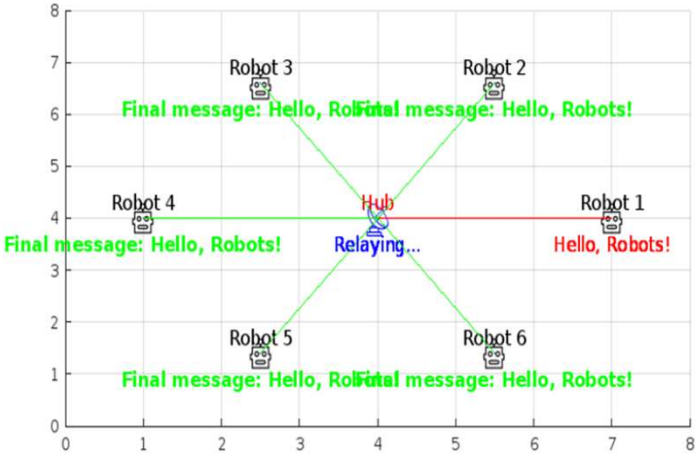
# Methodology

- Robots are arranged in a star topology with a central hub.
- MATLAB-based simulation models TCP and UDP communication.
- **TCP:** Reliable with acknowledgements and retransmissions.
- **UDP:** Lightweight and faster, but less reliable.
- Faults included: packet loss, delay, and jitter.
- Five communication scenarios tested: one-to-one, broadcast, many-to-one, sequential, and many-to-many.

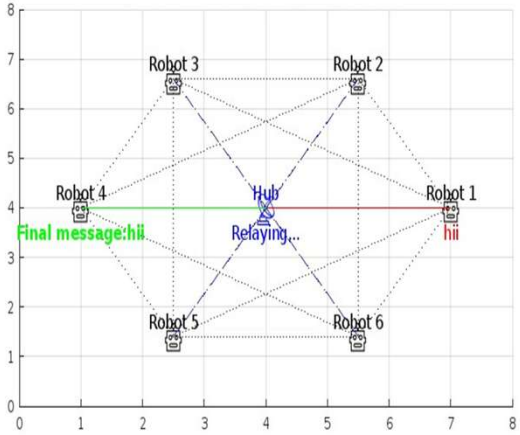
# Simulation Flow

- A sender robot generates a message for a target robot.
- The central hub receives the message and forwards it to the destination.
- **TCP:** Uses acknowledgements and retransmissions to ensure delivery.
- **UDP:** Sends messages without feedback, faster but less reliable.
- Network faults are simulated with packet loss (Bernoulli) and delay/jitter (Gaussian).
- Performance metrics recorded: latency, throughput, packet delivery ratio (PDR), and retransmissions.






**Scenario : 2**

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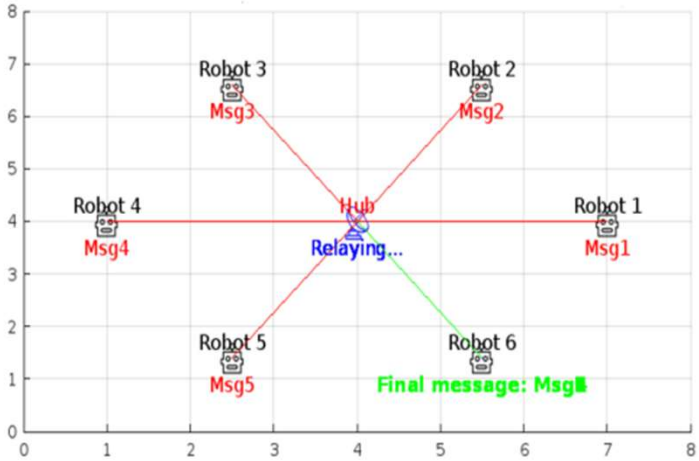


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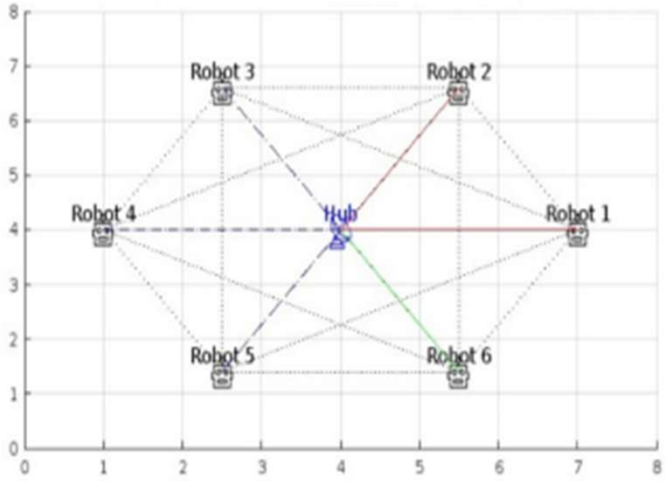
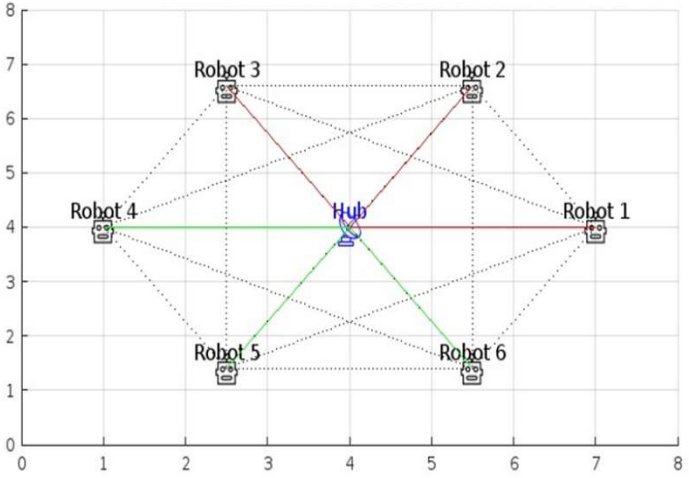



**Scenario : 4**

In the Simulation Outputs, blue lines represent the network topology, red lines represent data sent, and green lines represent data received.




**Scenario : 5**

# Simulation Results

| Scenario | Description | Latency(s) | PDR(%) | Retransmissions |
|---|---|---|---|---|
| 1 | Robot-to-Robot | 0.20 | 100 | 0 |
| 2 | One-to-All Broadcast | 0.28 | 96.67 | 3 |
| 3 | Multi-Source to Single | 0.33 | 93.33 | 4 |
| 4 | Sequential Few Sources | 0.22 | 100 | 0 |
| 5 | Multi-Destination Parallel | 0.35 | 91.67 | 5 |

# Conclusion

- Built a flexible MATLAB simulation for testing robot communications.
- TCP ensures delivery but increases latency.
- UDP is faster but risks missing data.
- Both protocols have trade-offs; choice depends on application.
- **Future work**:
  - Test with moving robots
  - Add more nodes
  - Try hybrid switching between TCP & UDP.

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