School of Computer Science and Communication Systems
Master in Computer Science

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Bandwidth efficient object recognition for drone swarms

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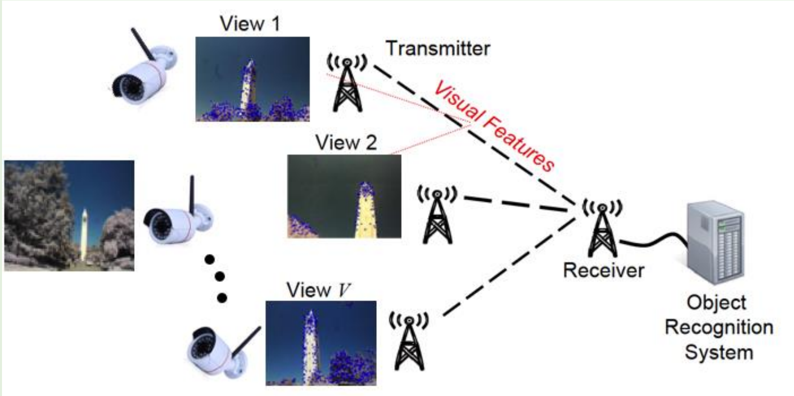
Project Overview

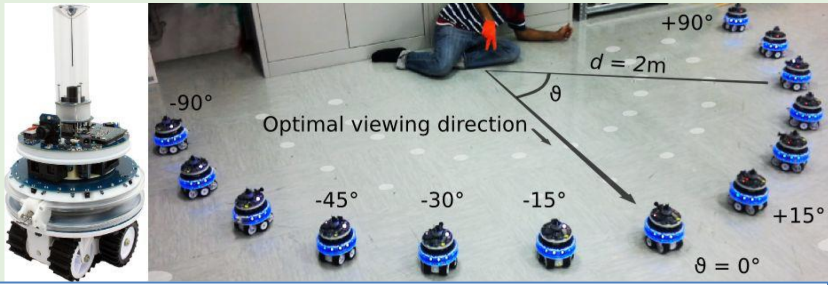
- Motivation
  - Detection Accuracy: prediction by single drone may be unreliable
    - False positives and false negatives can occur
  - Consensus: autonomous swarms may need to agree on whether a given target is present
  - Bandwidth efficiency: especially relevant in urban environment
- Goal
  - Determine the presence/absence of a target object with high accuracy

Related Work

- A. Rahimpour *et al.,* “Distributed Object Recognition in Smart Camera Networks”, 2016 IEEE Int. Conf. on Image Processing (ICIP), 2016.
  - Feature extraction performed by each camera
  - Features sent to a base station, which performs object detection → no autonomy of devices
  - Lack of an autonomous set of devices that triggers other events

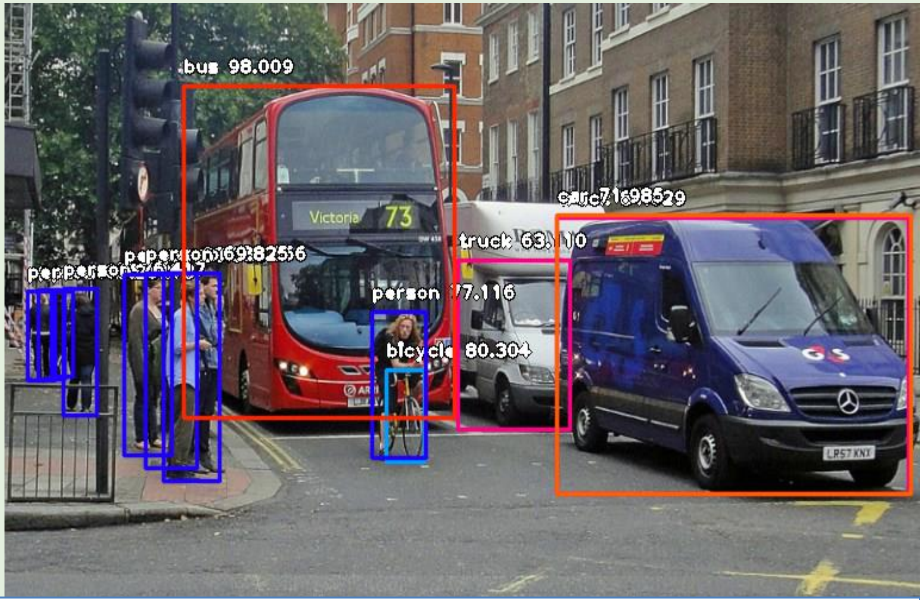


- J. Lee et al., “Real-Time Object Detection for Unmanned Aerial Vehicles based on Cloud-based Convolutional Neural Networks”, First IEEE International Conference on Robotic Computing (IRC), 2017.
  - Cloud-based object detection
  - Applied to aerial vehicles, but no data aggregation
- A. Giusti et al., "Cooperative sensing and recognition by a swarm of mobile robots“, IEEE/RSJ International Conference on Intelligent Robots and Systems, 2012.
  - Interesting communication and consensus
  - Human-computer interaction
  - Different setup, different goal
  - Classification task

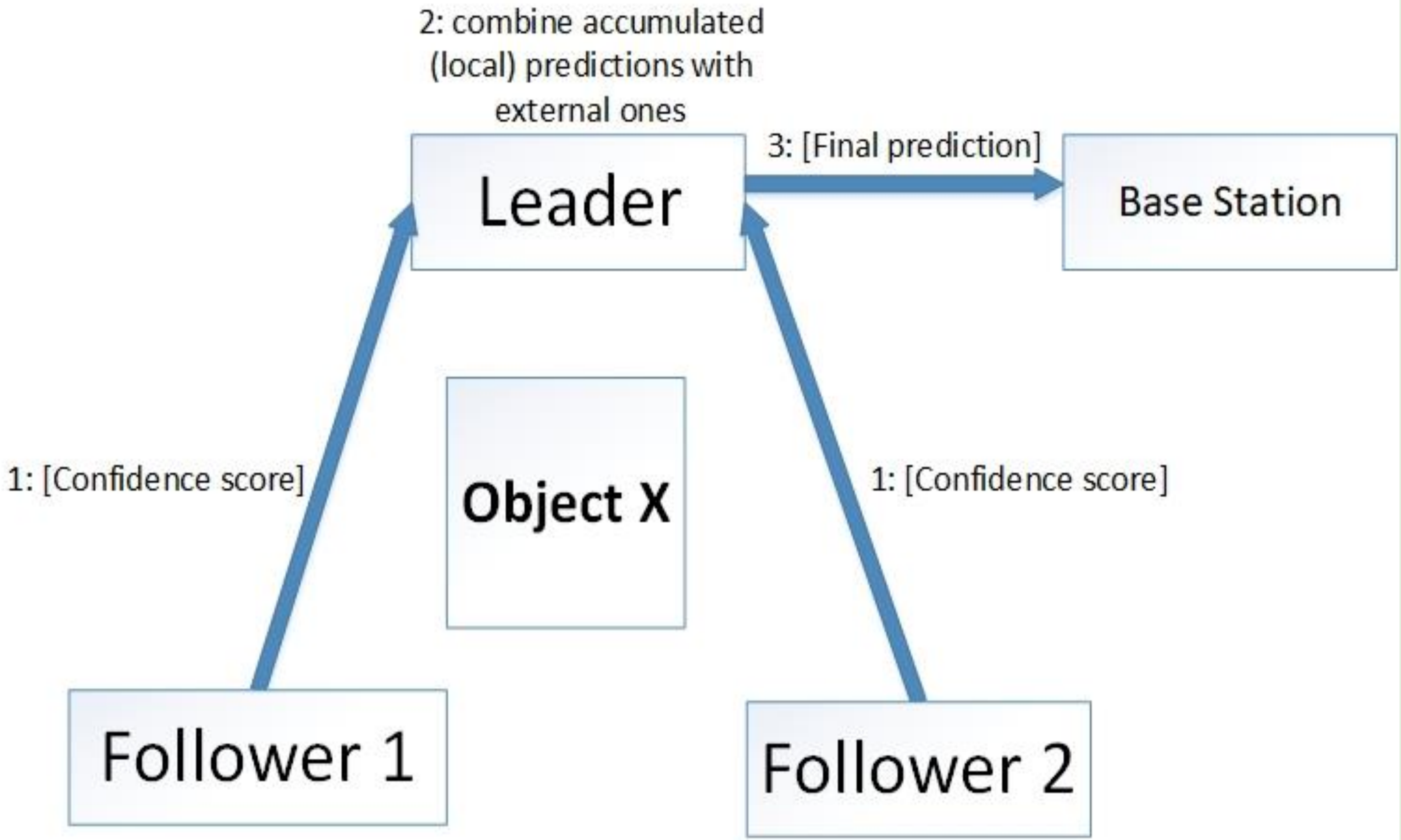


Hardware Selection and Validation

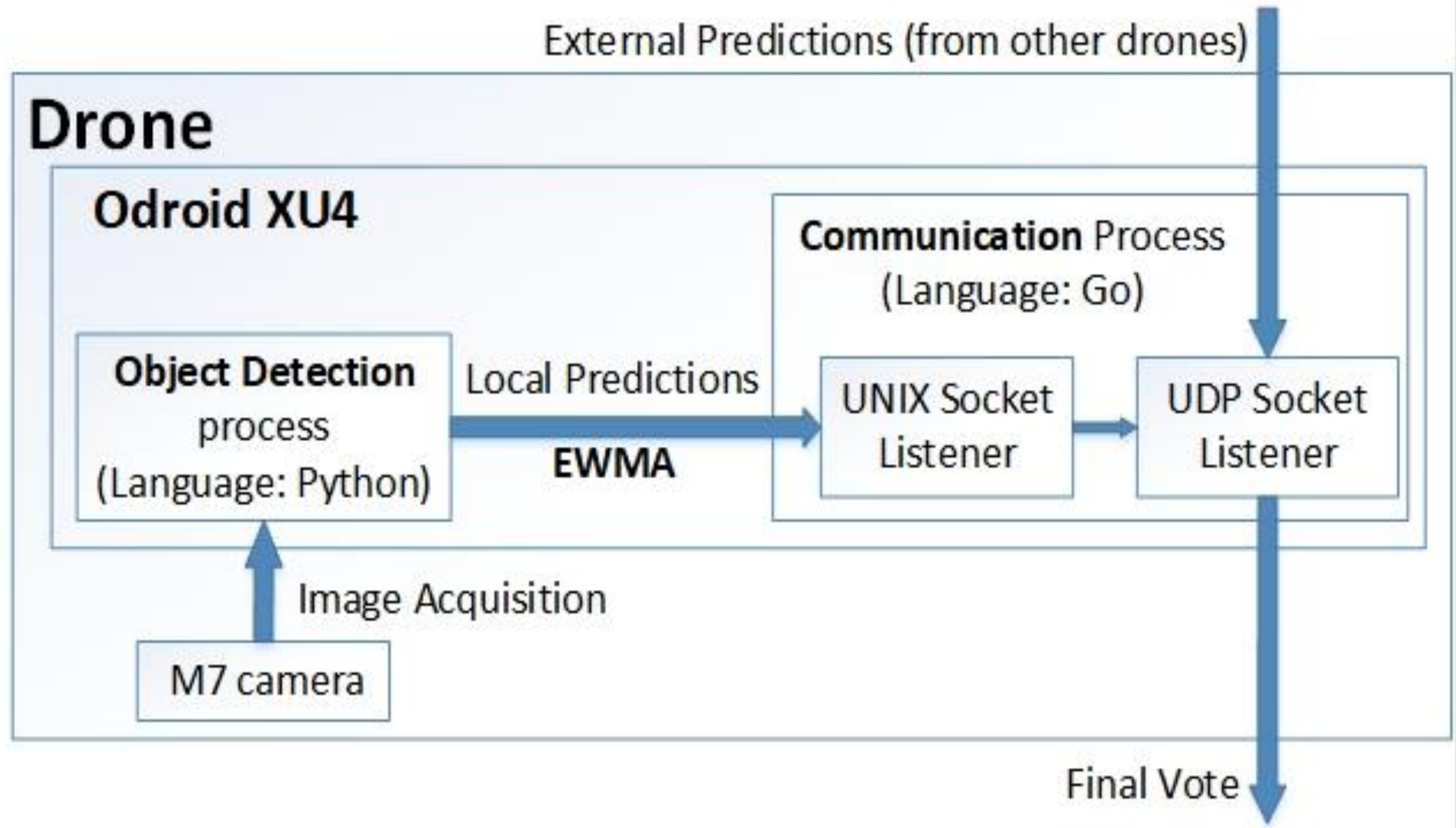
- Hardware selection
    - Single-board computers: Odroid XU4
    - Image Acquisition: OpenMV M7
    - Connectivity: WiFi Module 5
- **Connectivity tests**
    - Adhoc mode compatibility
    - Network throughput
    - Network stability
- **Object detection tests**
    - Setup of a deep learning framework
    - MSCOCO pre-trained neural network



Protocol Design: Inter-host Communication



Protocol Design: Intra-host Computations

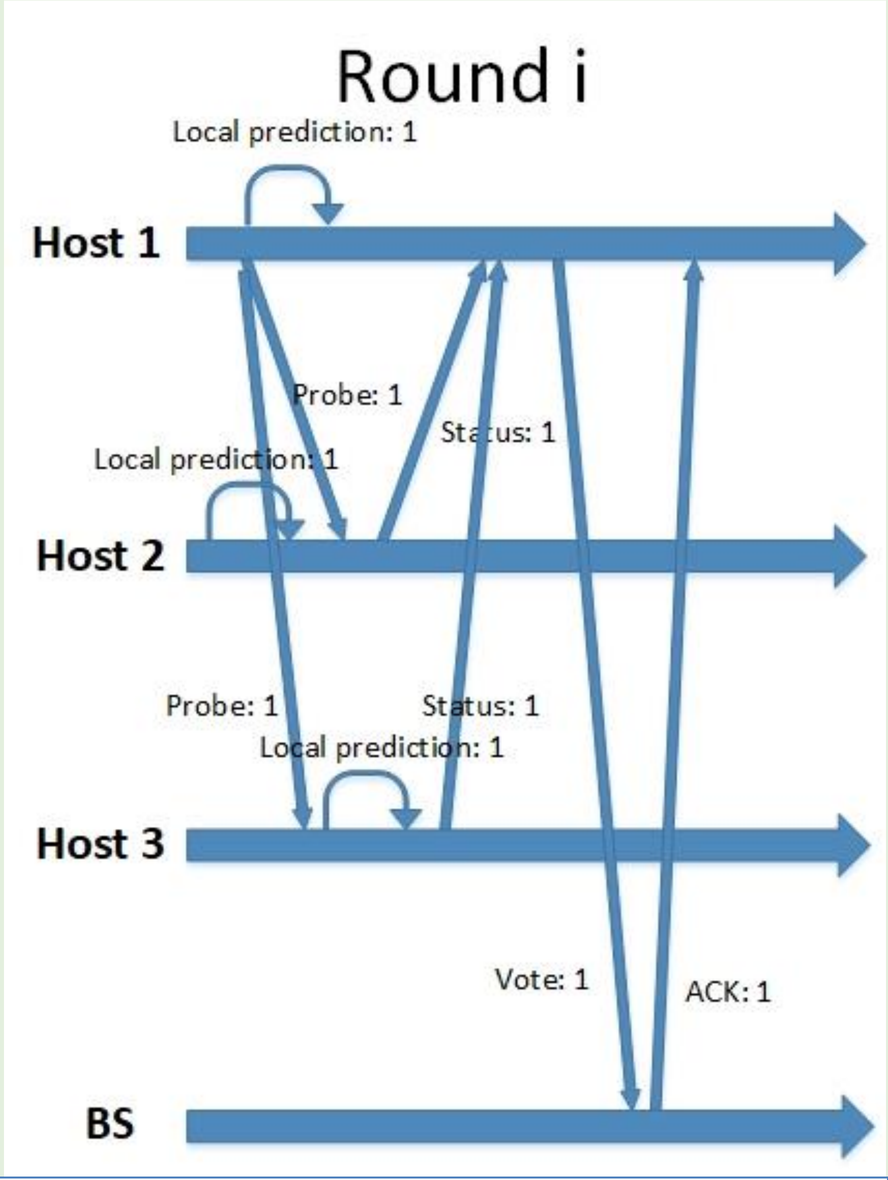


Protocol Design: Leader Election

- Assumption: the number of hosts (N) in the network is known
- Any host can be the leader
  - As long it knows who the leader is
- One leader per round
  - It changes at each round
  - More system resiliency
  - Very simple mechanism
- Leader ID = Round ID % N
  - N = #hosts
- The leader classifies an object as present iff #positive predictions > M
  - M = N/K

Protocol: Execution Example

- Limited amount of exchanged messages
  - N-1 probes messages → 1 single broadcast
  - N-1 status messages
  - 1 final vote + ACK
  - N-1 start round messages → 1 single broadcast



Protocol Validation: Data Fusion

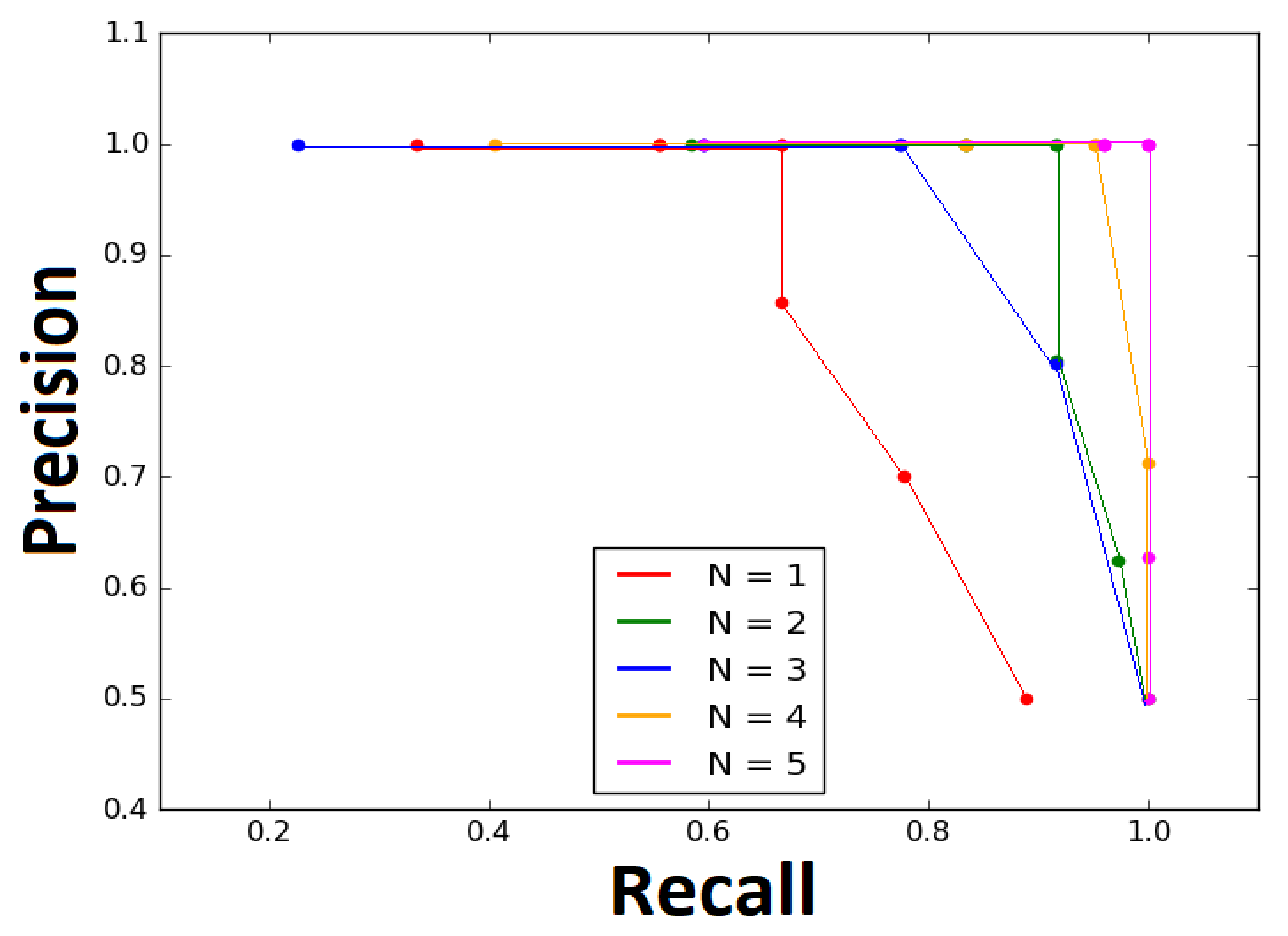
- Precision: TP / (TP+FP)
  - High if there are few false positives
- Recall: TP / (TP + FN)
  - High if there are few false negatives

- Two scenarios
- With the real object
  - Not all optimal views

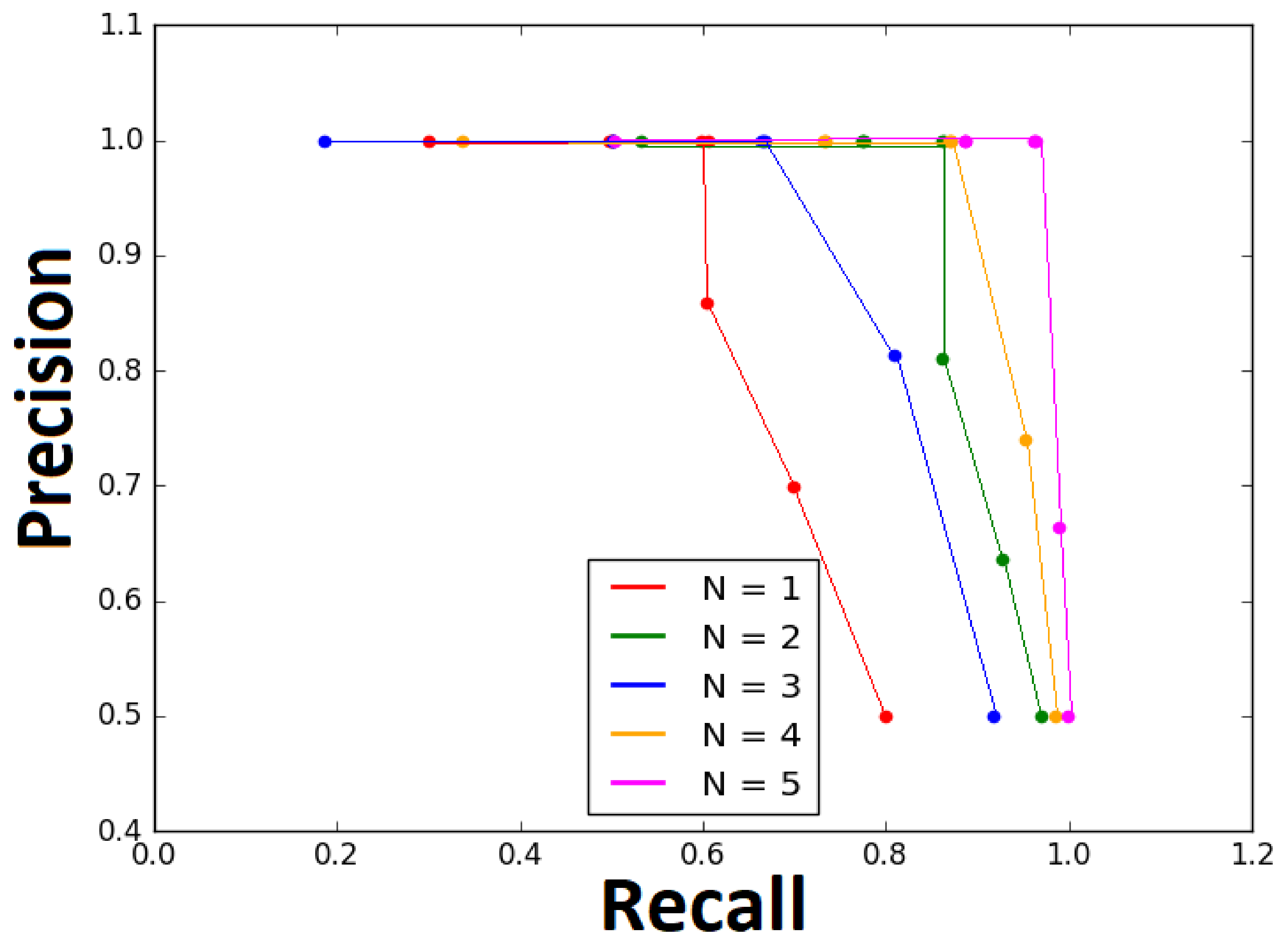
- With the fake object
  - Some views resemble the real object

- Simulation
  - Take K pictures
  - Fix N
  - For each possible combination of N hosts in K positions (for a total of $C_{k,n}$), compute the prediction with the data fusion mechanism

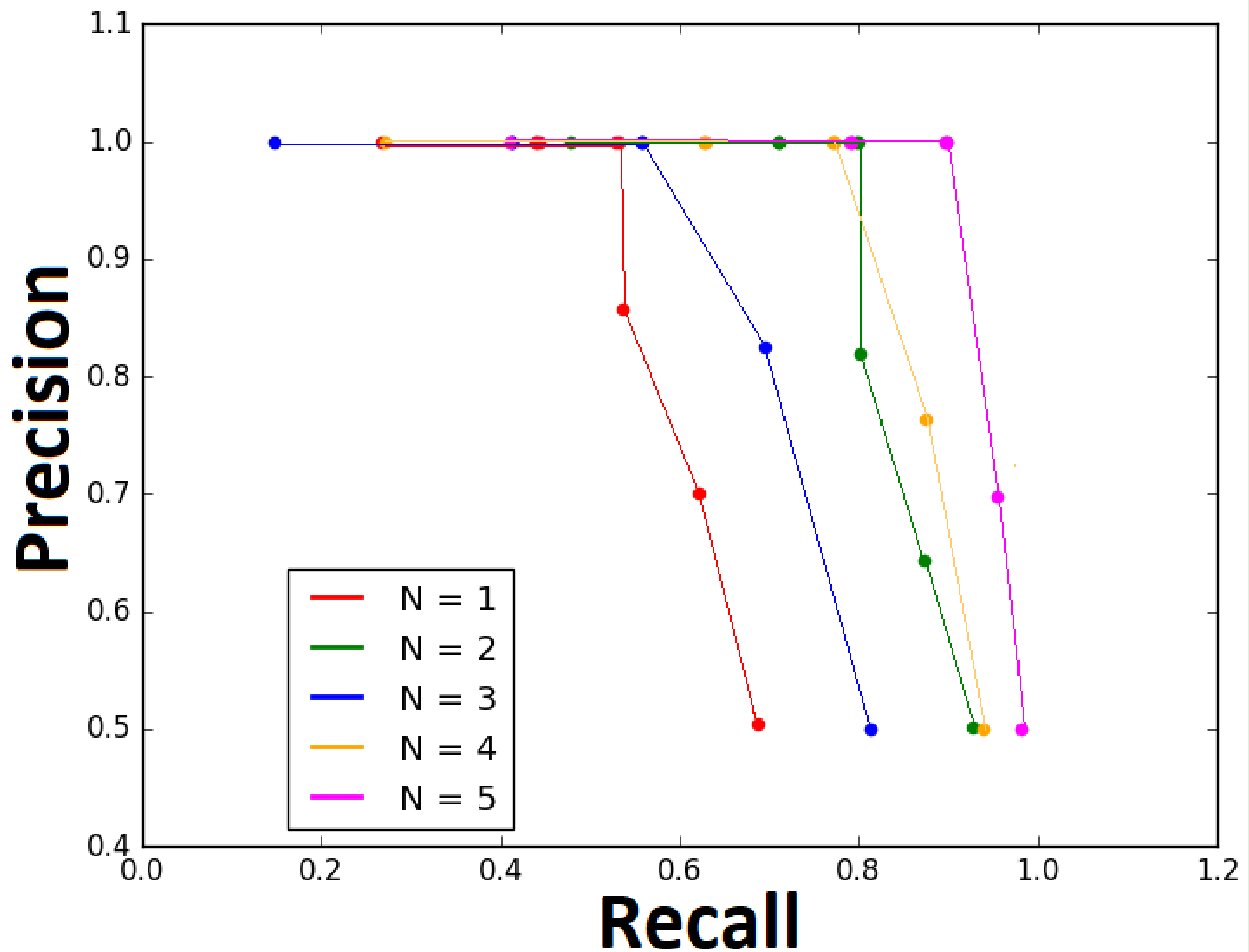
Protocol Validation: Data Fusion, P(loss) = 0



Protocol Validation: Data Fusion, P(loss) = 10%

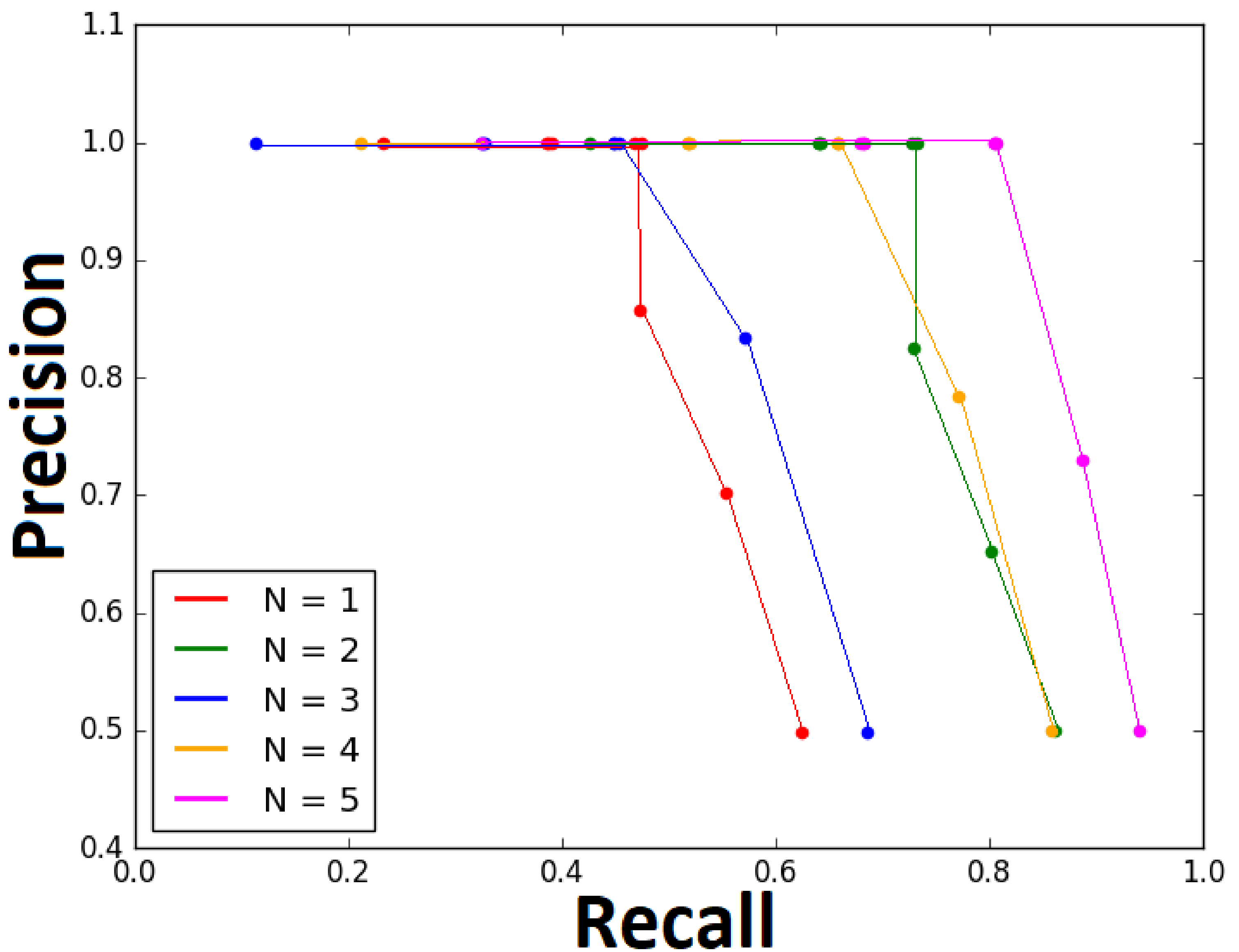


Protocol Validation: Data Fusion, P(loss) = 20%

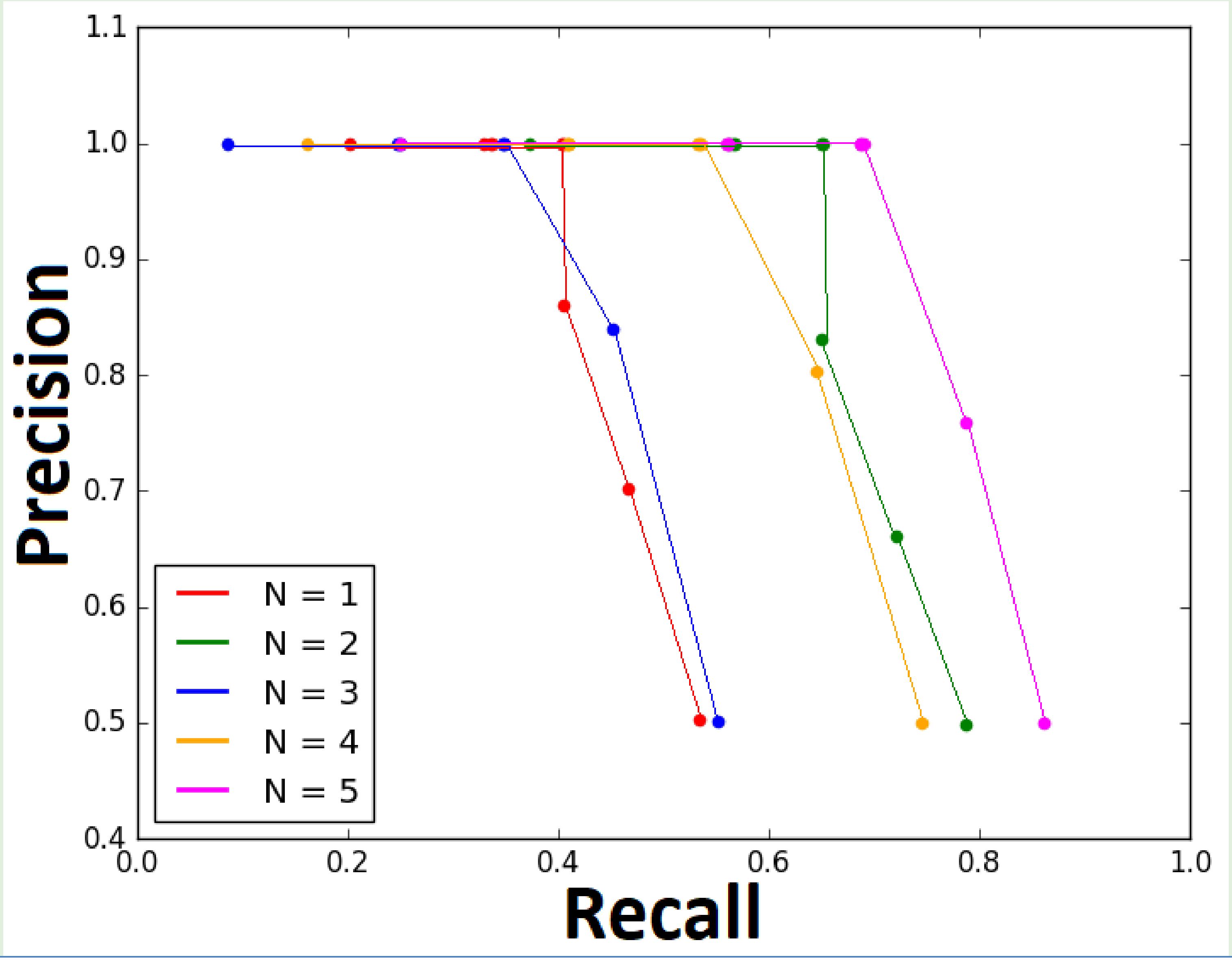


Introduction – Related Work – How? – **Experiments** – Conclusion

Protocol Validation: Data Fusion, P(loss) = 30%

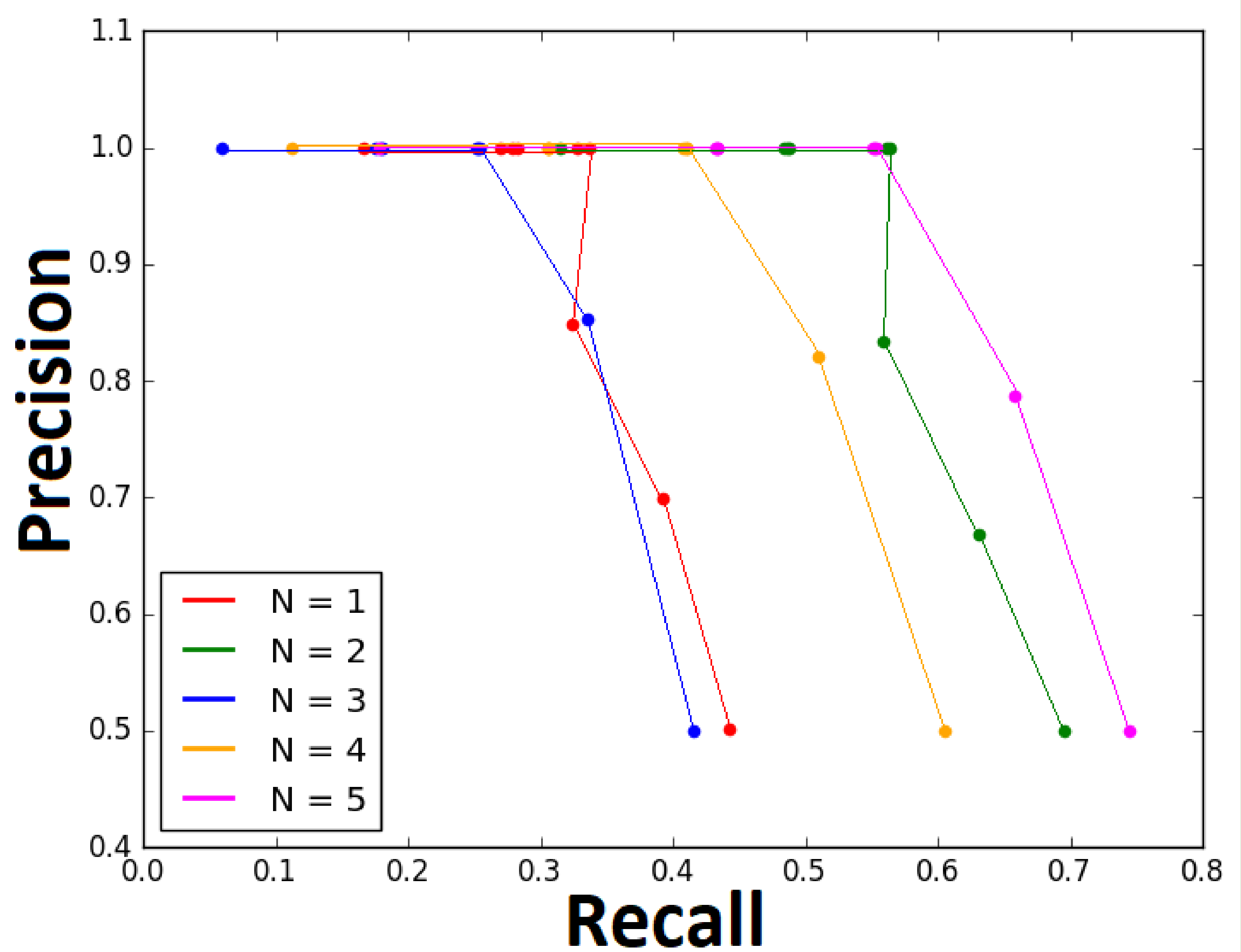


Protocol Validation: Data Fusion, P(loss) = 40%



Introduction – Related Work – How? – **Experiments** – Conclusion

Protocol Validation: Data Fusion, P(loss) = 50%



Protocol Validation: Protocol Convergence

- Simple setup
  - Three devices
  - Same object as data aggregation validation

- Two distinct runs
- With the real object
  - False negatives eliminated

- With the fake object
  - False positives eliminated

Conclusion

- Distributed object detection system implemented
  - Implemented from scratch
  - Scalable and modular system
  - Improvements over single-host system have been shown
  - Main goal achieved

- Future Work
  - Gather more data
  - Re-train the model
  - Deploy the protocol on more devices
  - Perform tests on flying/moving drones

THANK YOU
FOR
YOUR
ATTENTION!
ANY QUESTIONS?