

School of Computer Science and Communication Systems
Master in Computer Science



ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Bandwidth efficient object recognition for drone swarms

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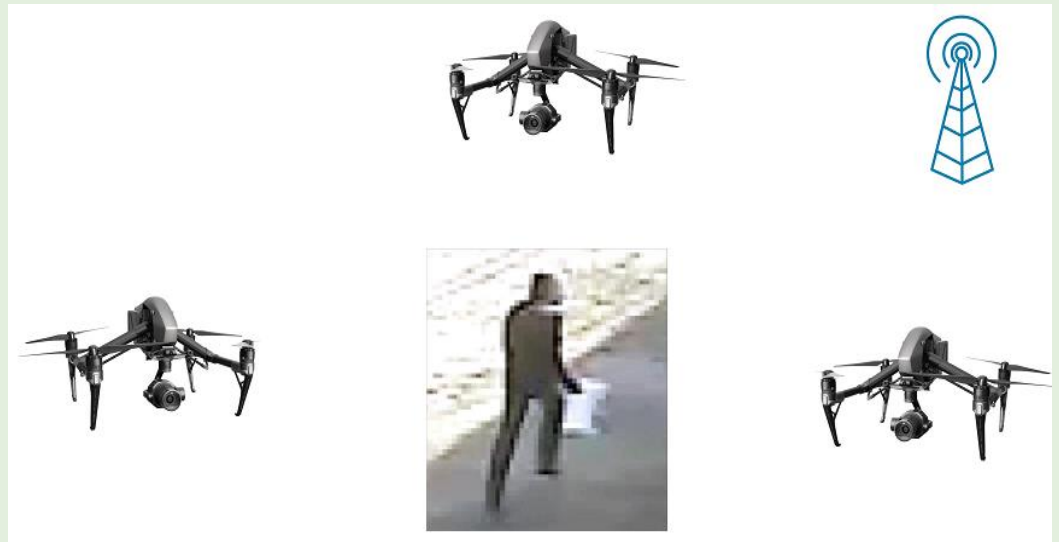
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Project Overview

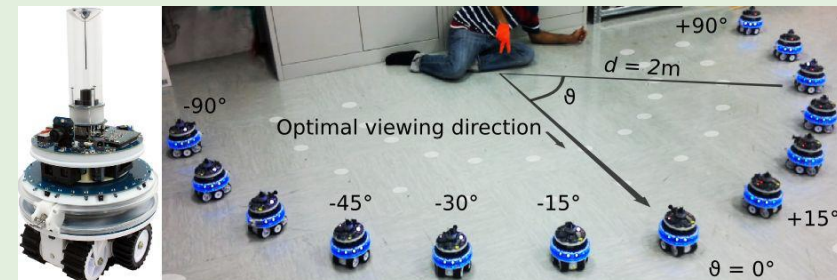
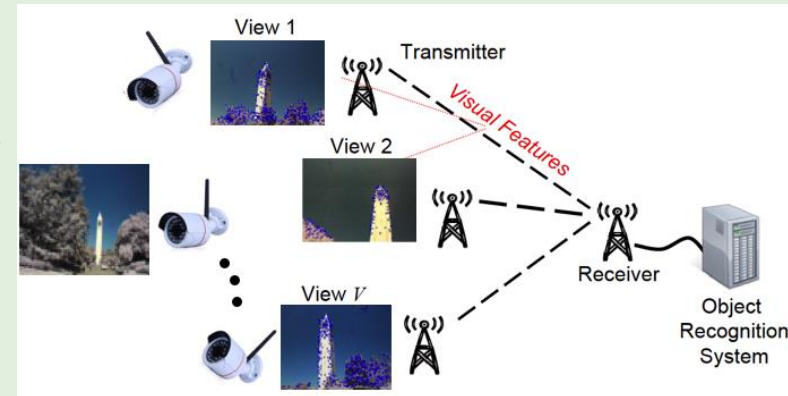
- Motivation
 - Detection Accuracy: prediction by single drone may be unreliable
 - False positives and false negatives can occur
 - Consensus: autonomous swarms may need to agree on whether a given target is present
 - Bandwidth efficiency: especially relevant in urban environment
- Goal
 - Determine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



Introduction – Related Work – How? – Experiments – Conclusion

Related Work

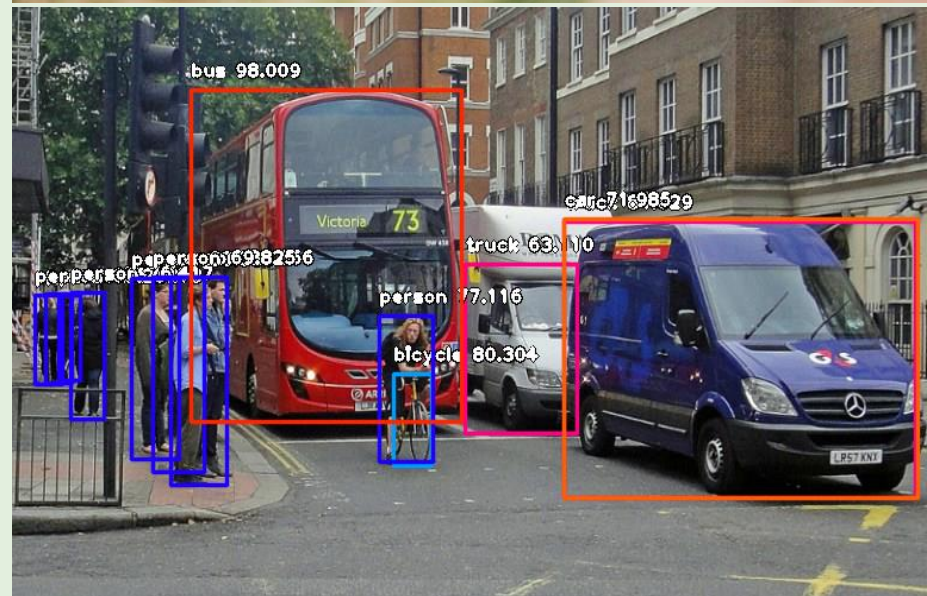
- A. Rahimpour *et al.*, “Distributed Object Recognition in Smart Camera Networks”, 2016 IEEE Int. Conf. on Image Processing (ICIP), 2016.
 - Feature extraction performed by each camera
 - Features sent to a base station, which performs object detection → no autonomy of devices
 - Lack of an autonomous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



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

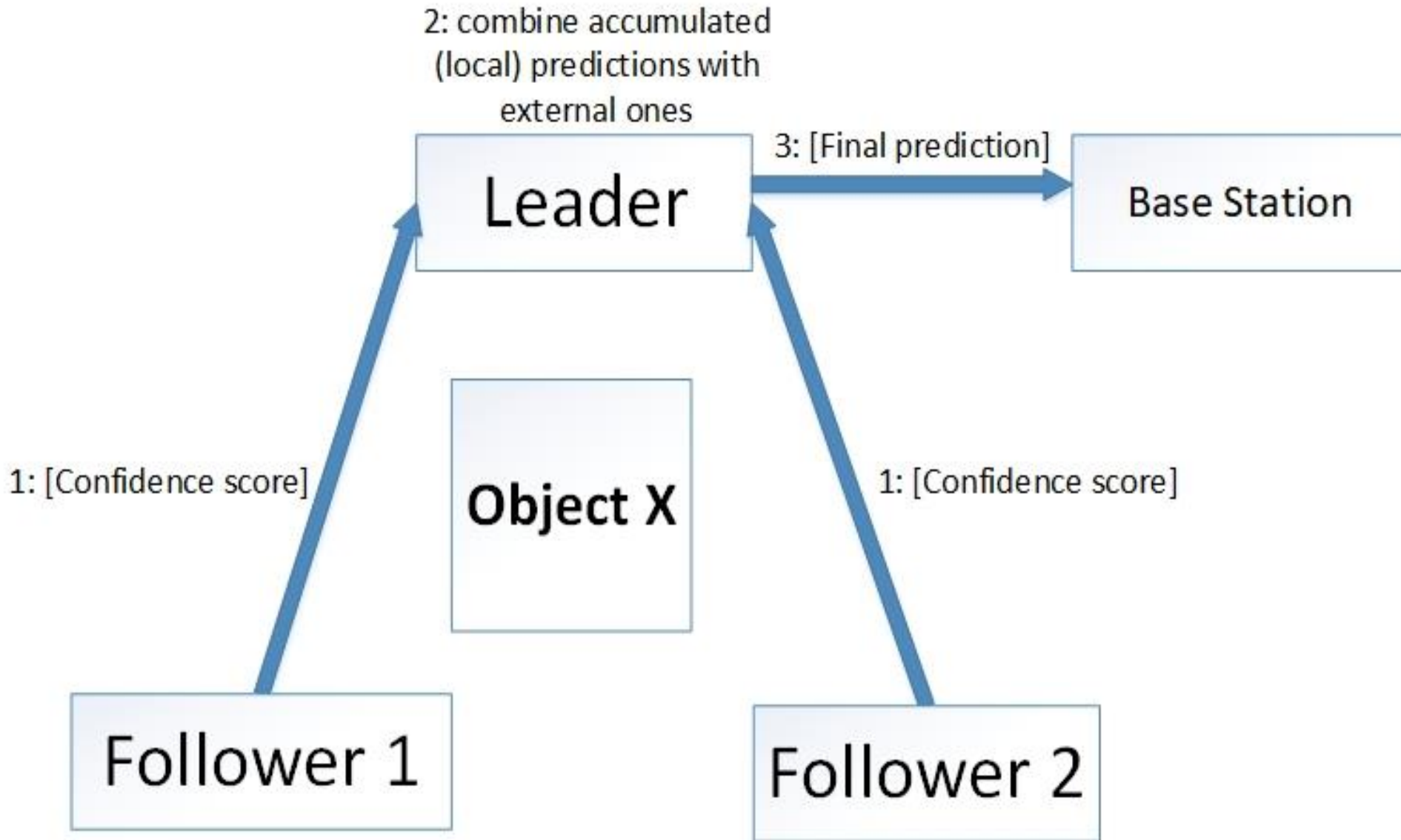
Hardware Selection and Validation

- 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

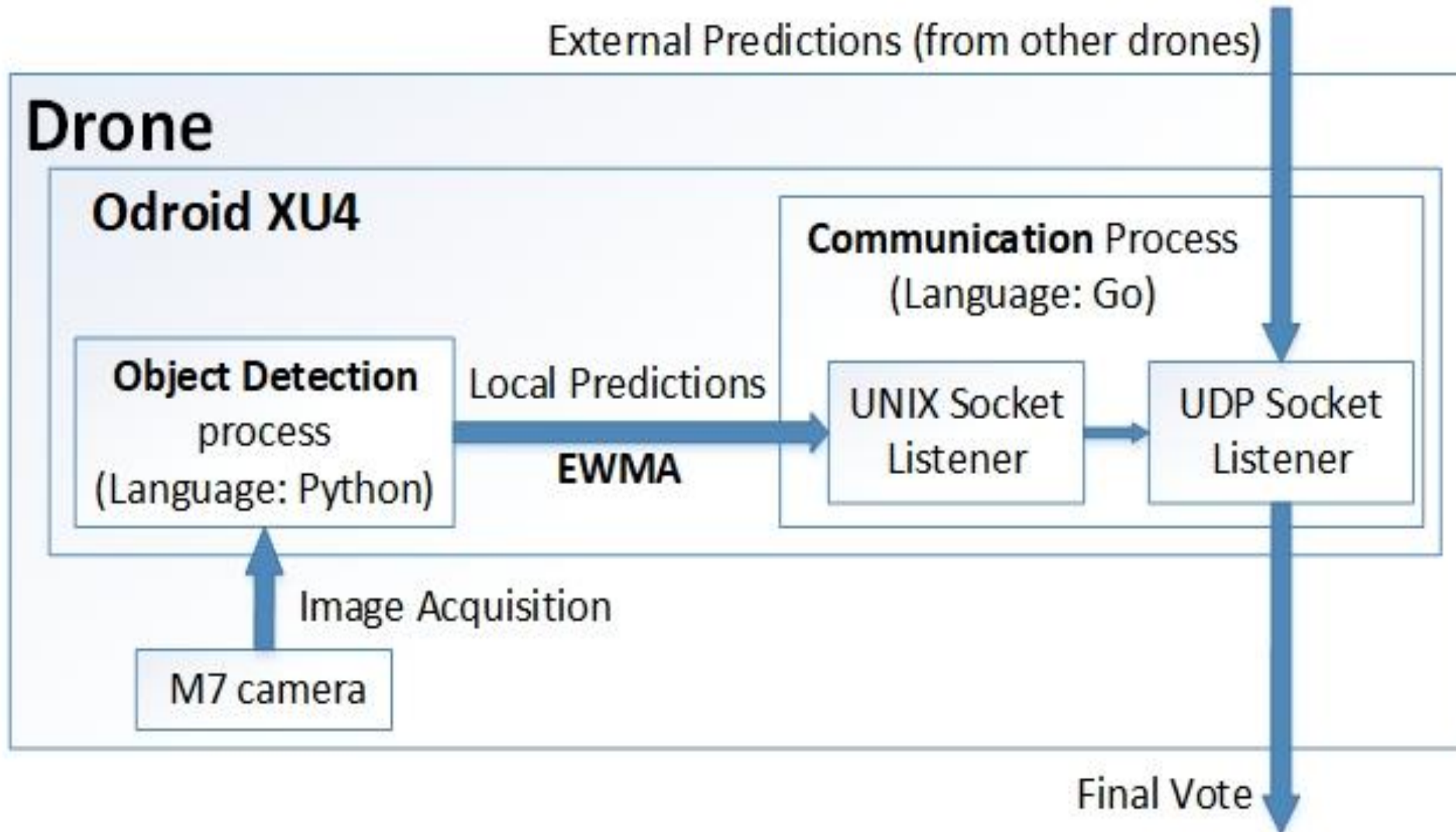


Introduction – Related Work – **How?** – Experiments – Conclusion

Protocol Design: Inter-host Communication



Protocol Design: Intra-host Computations

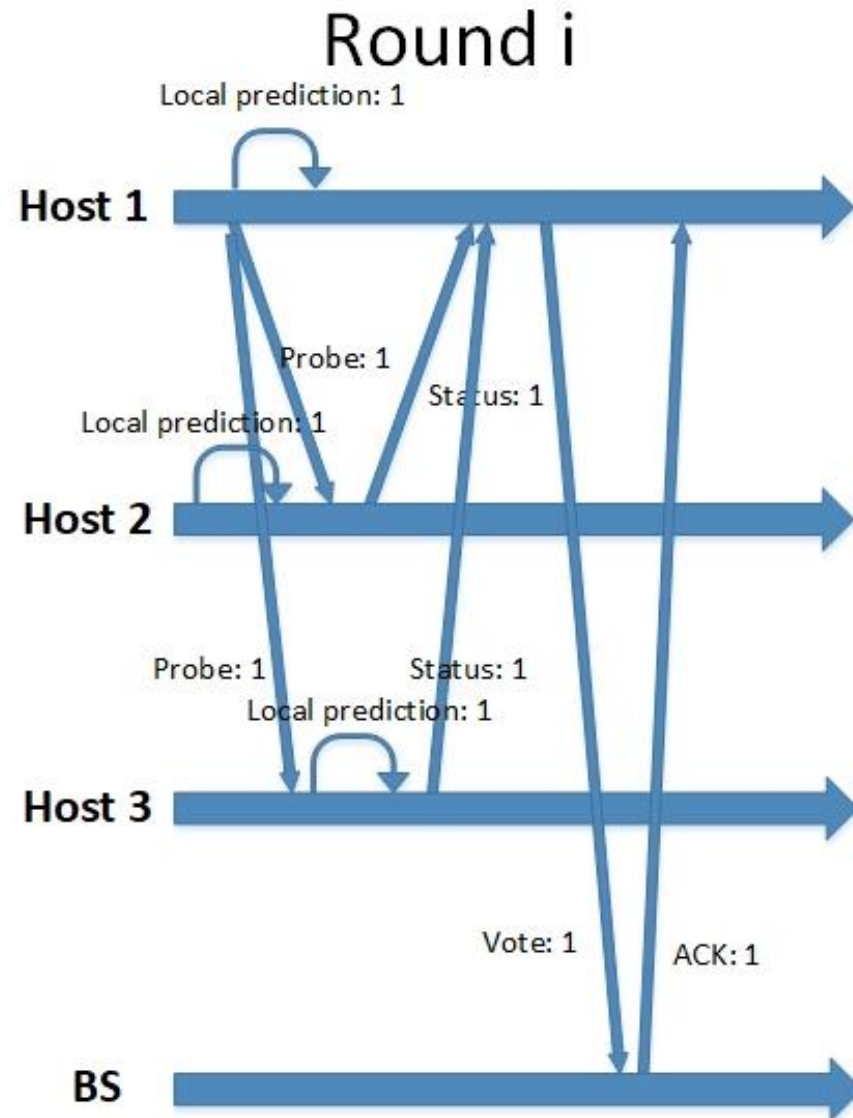


Protocol Design: Leader Election

- 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
 - $N = \text{\#hosts}$
- The leader classifies an object as present iff $\text{\#positive predictions} > M$
 - $M = N/K$

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

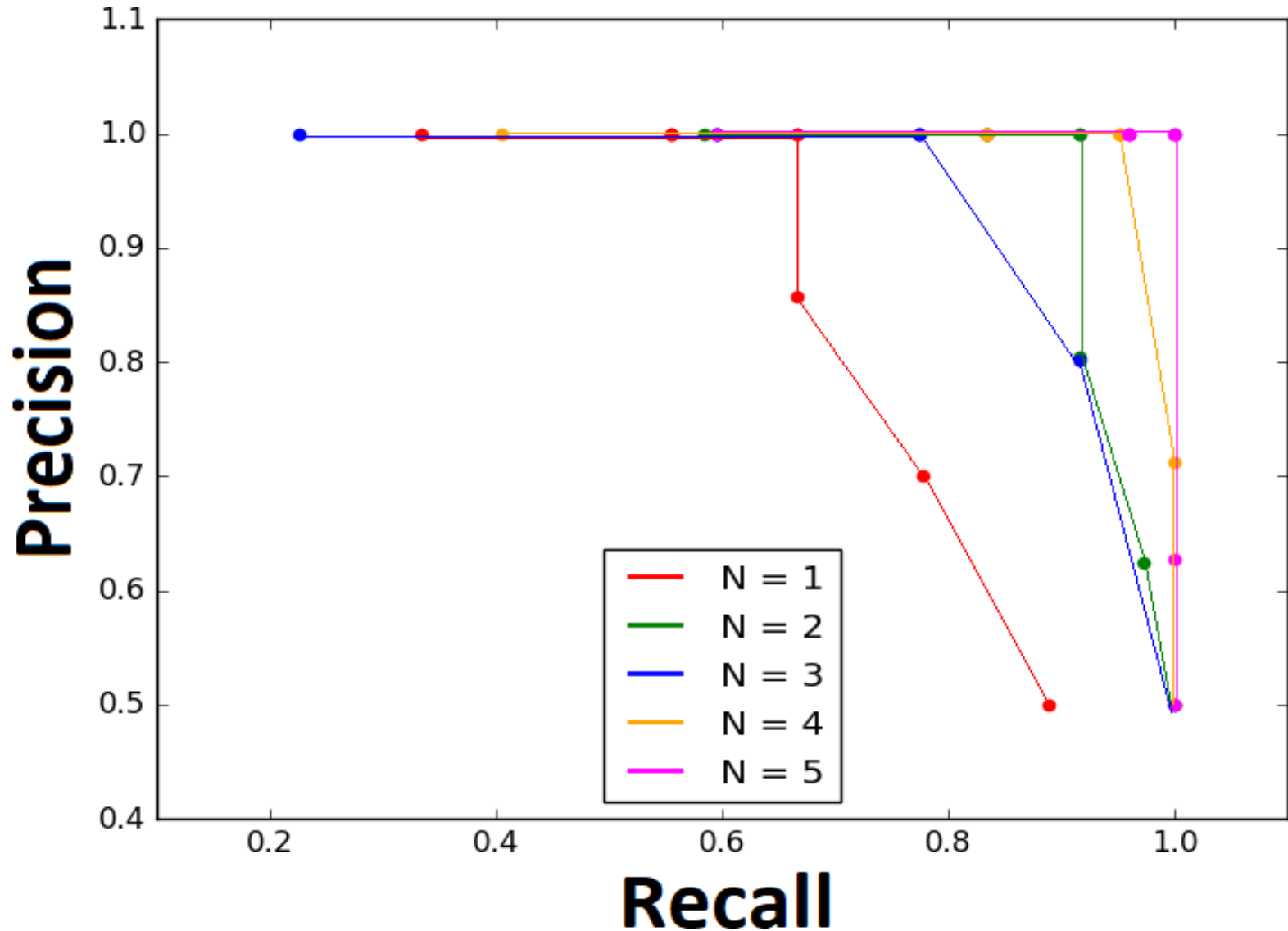


Protocol Validation: Data Fusion

- 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

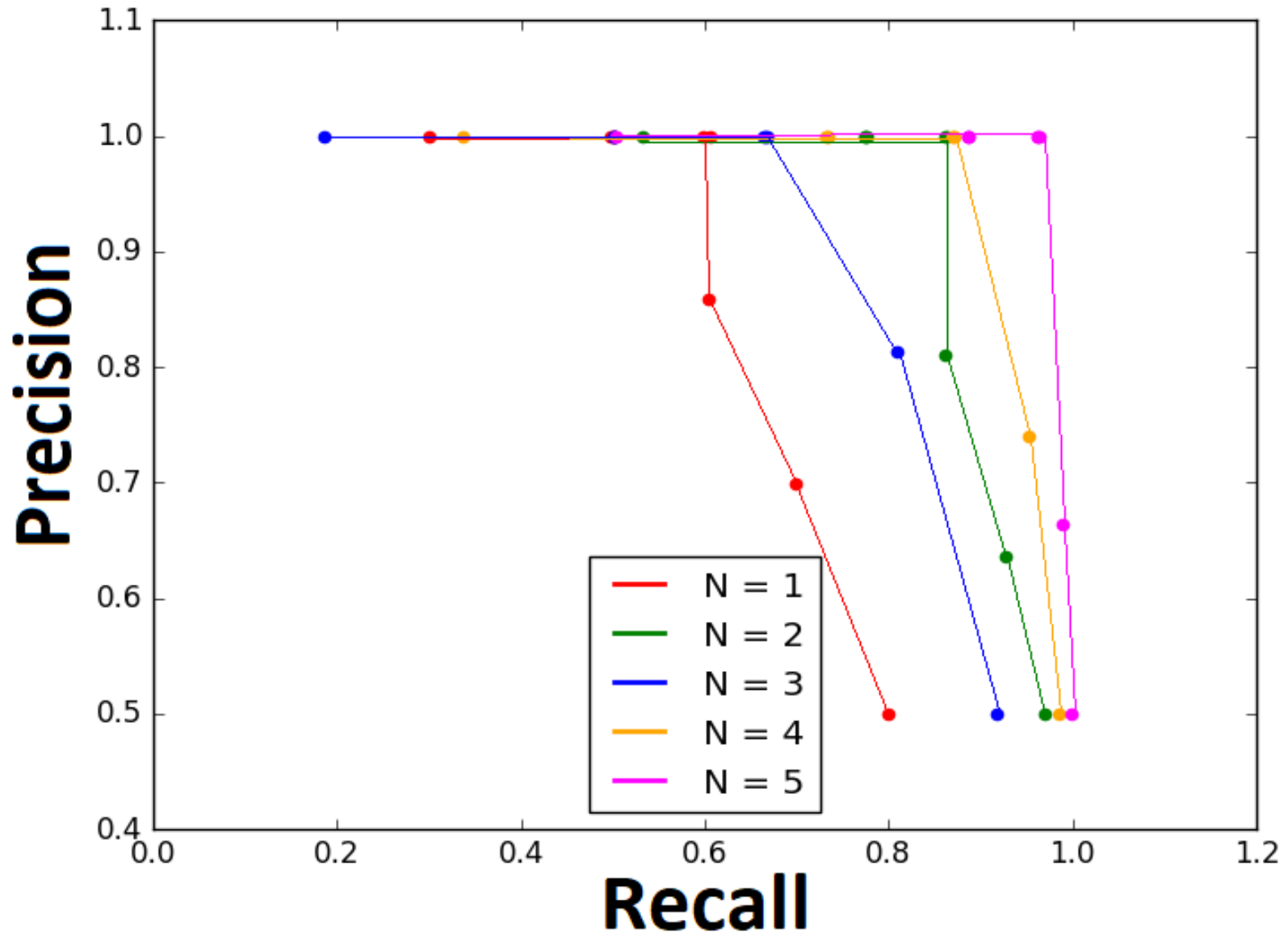


Protocol Validation: Data Fusion, $P(\text{loss}) = 0$



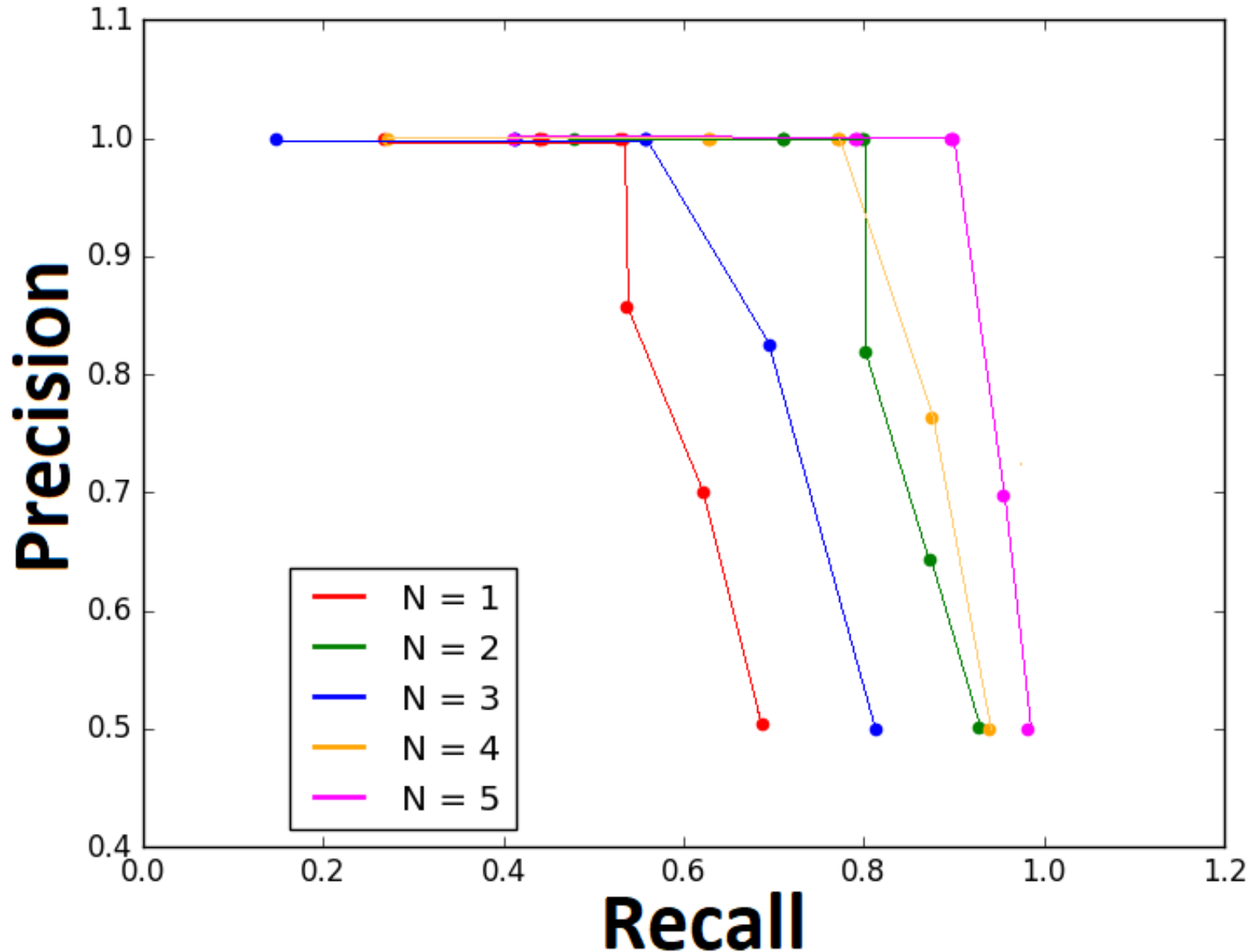
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Protocol Validation: Data Fusion, $P(\text{loss}) = 10\%$

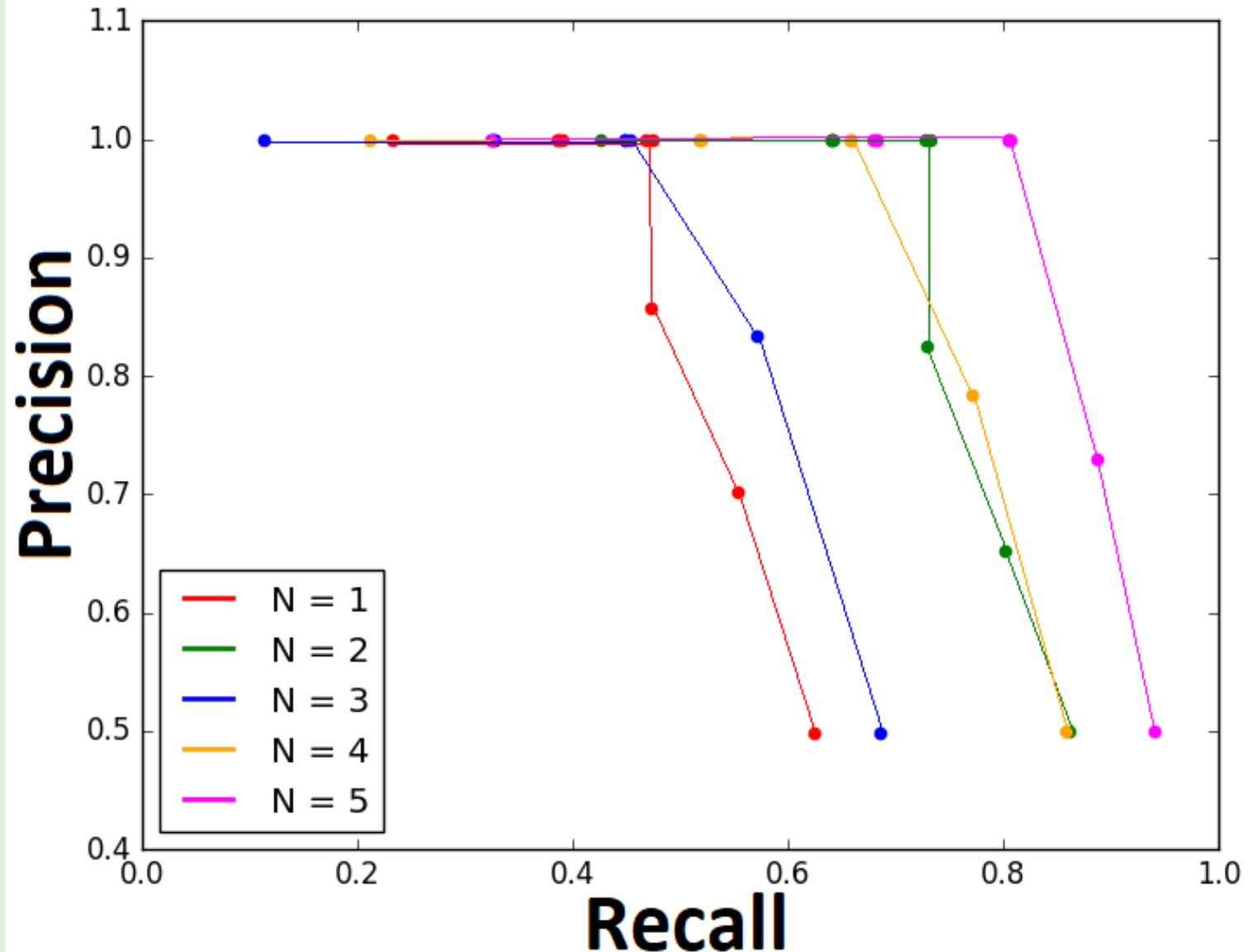


Introduction – Related Work – How? – **Experiments** – Conclusion

Protocol Validation: Data Fusion, $P(\text{loss}) = 20\%$

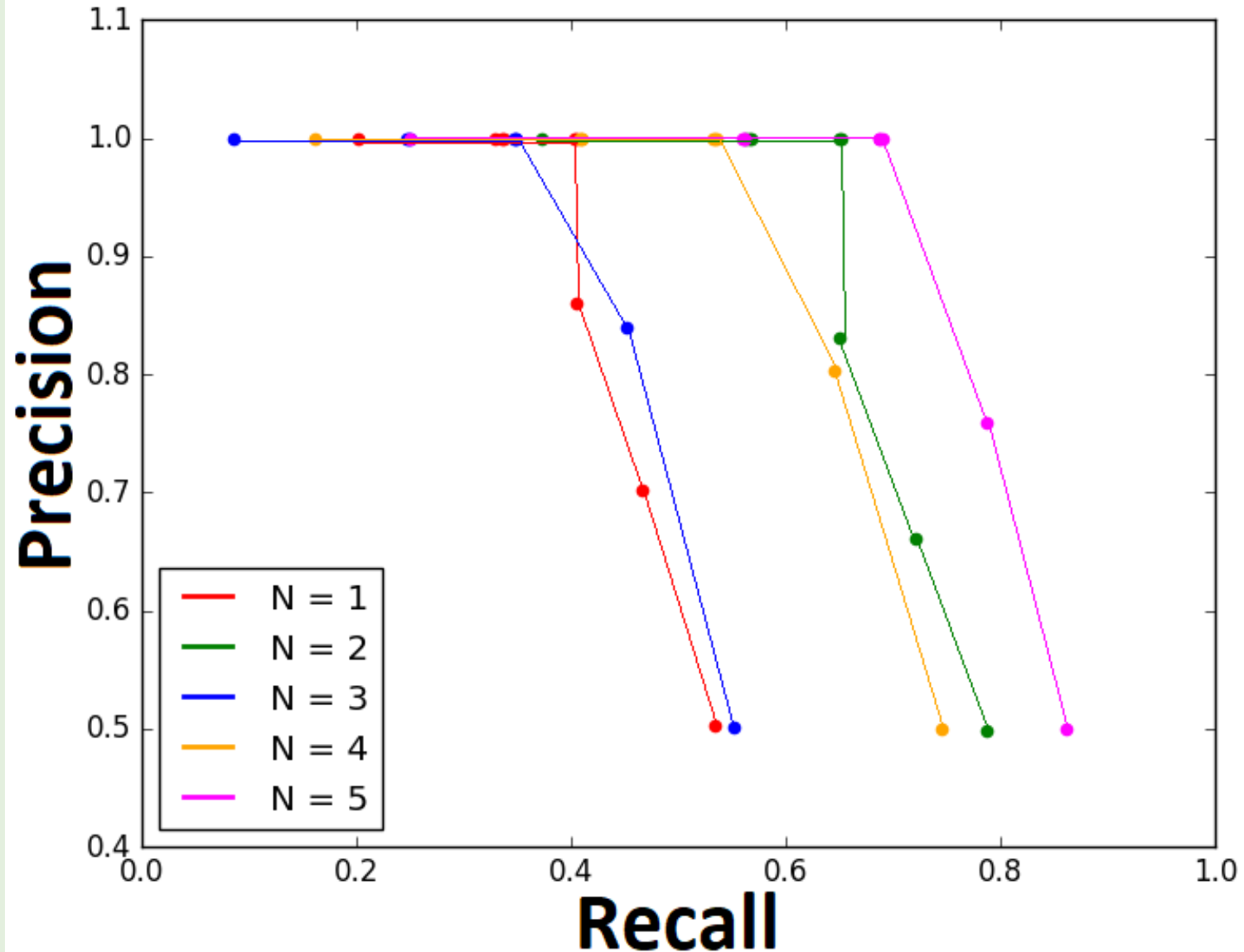


Protocol Validation: Data Fusion, $P(\text{loss}) = 30\%$



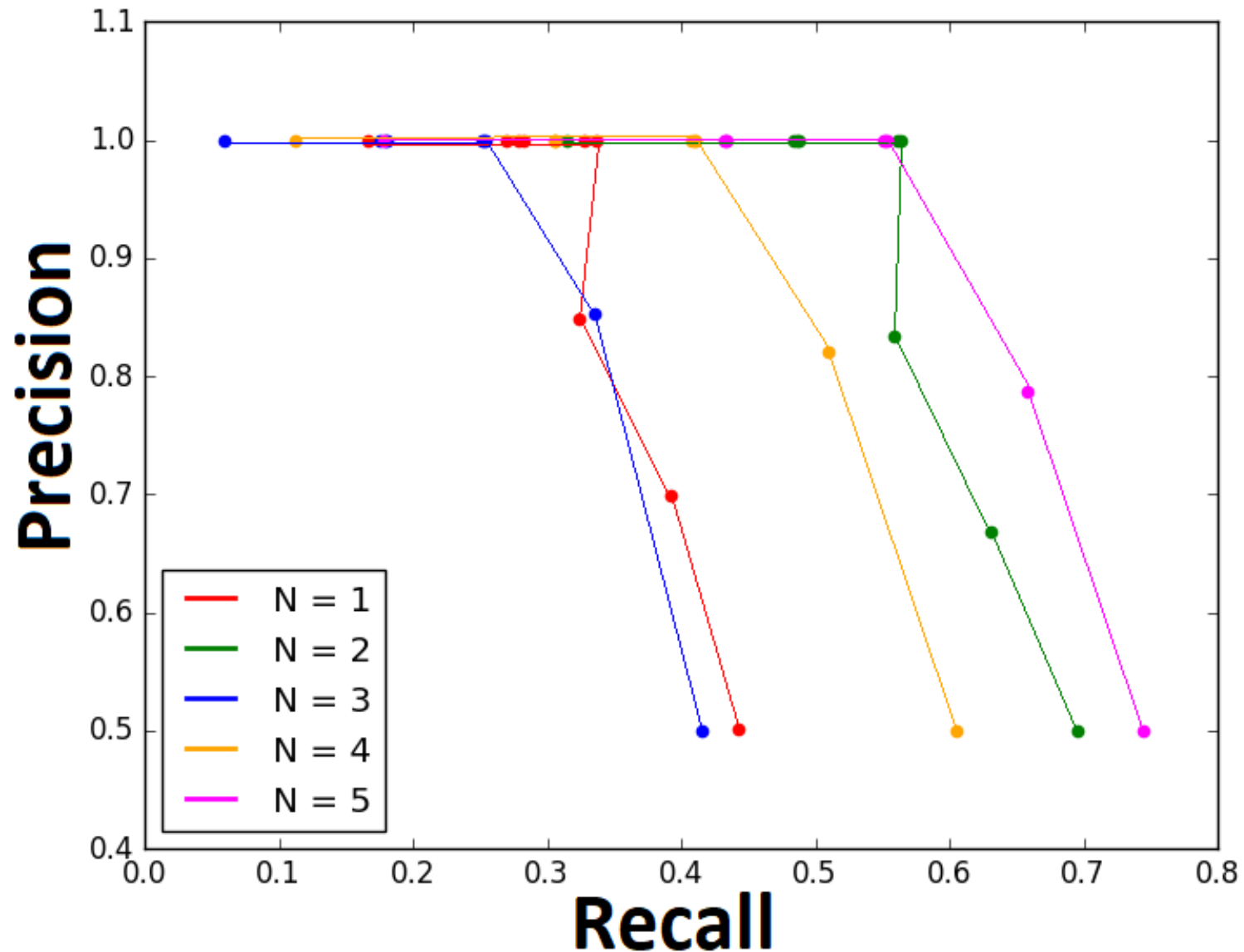
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Protocol Validation: Data Fusion, $P(\text{loss}) = 40\%$



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

Protocol Validation: Data Fusion, $P(\text{loss}) = 50\%$



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

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?**