Neighbour consensus for distributed visual tracking

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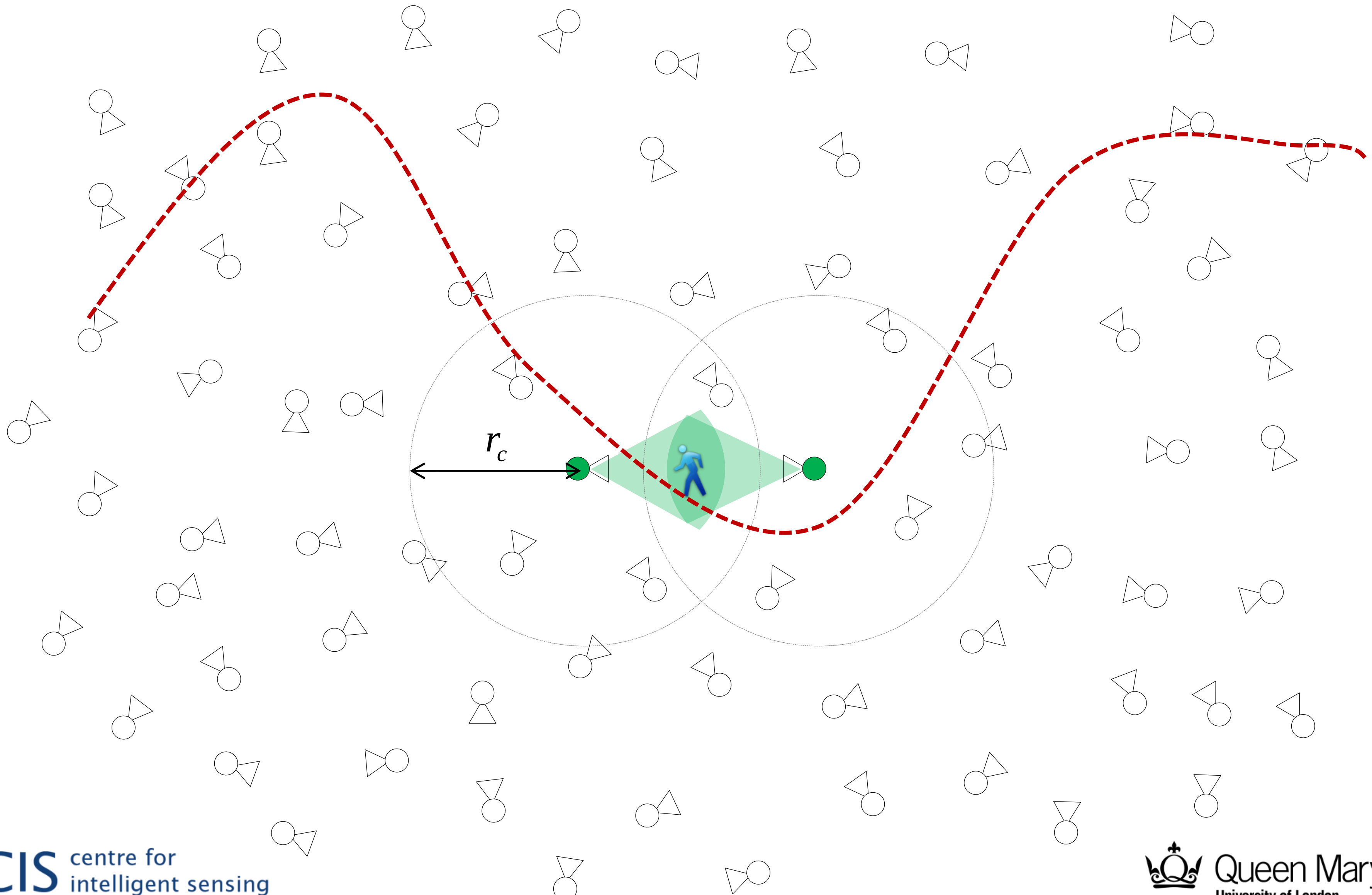
Motivation

r_c : communication range

: viewing node



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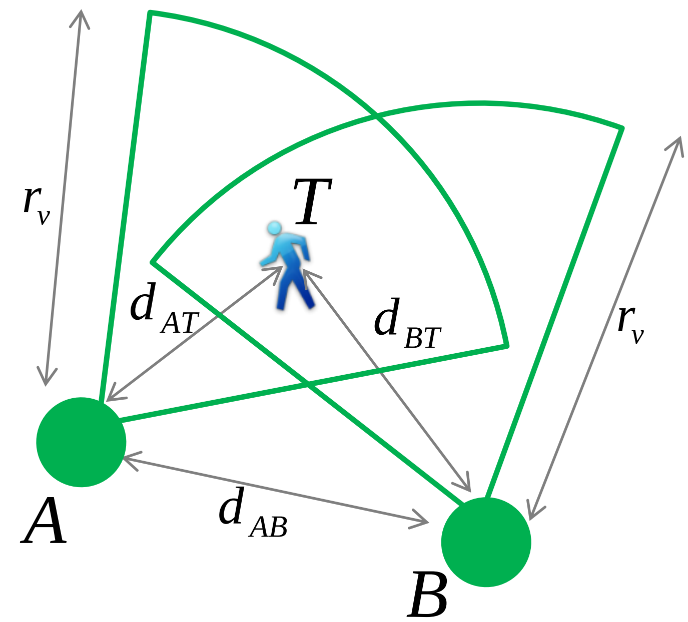
Introduction

r_c : communication range
r_v : viewing range

- Target tracking
  - wireless cameras
  - large network
  - limited communication range
    - $r_c < 2r_v$
- Information fusion
- Target handover
- Limited resources
  - power and load



$$d_{AT} \le r_v$$
$$d_{BT} \le r_v$$
$$d_{AB} \le d_{AT} + d_{BT}$$
$$\boxed{d_{AB} \le 2r_v}$$

Assumptions

- Target
  - single
  - always observable
  - speed $< \frac{2r_v}{\Delta k}$
- Cameras
  - limited FOV
  - calibrated
  - homogeneous
  - Gaussian noise
  - *no false positives*
- Network
  - static topology
  - large network
    - $diam \geq 2r_v$
  - single-hop connectivity
  - *no packet losses*
  - *no link failures*

FOV : field of view
Δk : time step size
r_v : viewing range

State of the art

Reference	No routing (and) $r_c < 2\,r_v$	Routing (or) $r_c >= 2\,r_v$	Fusion scheme
[Song2010]		✓	Consensus
[Kamal2013]	✓		Consensus
[Katragadda2014]	✓		Consensus
[Nastasi2011]		✓	Token passing
[SanMiguel2014]		✓	Clustering
[SanBernabe2014]		✓	Clustering

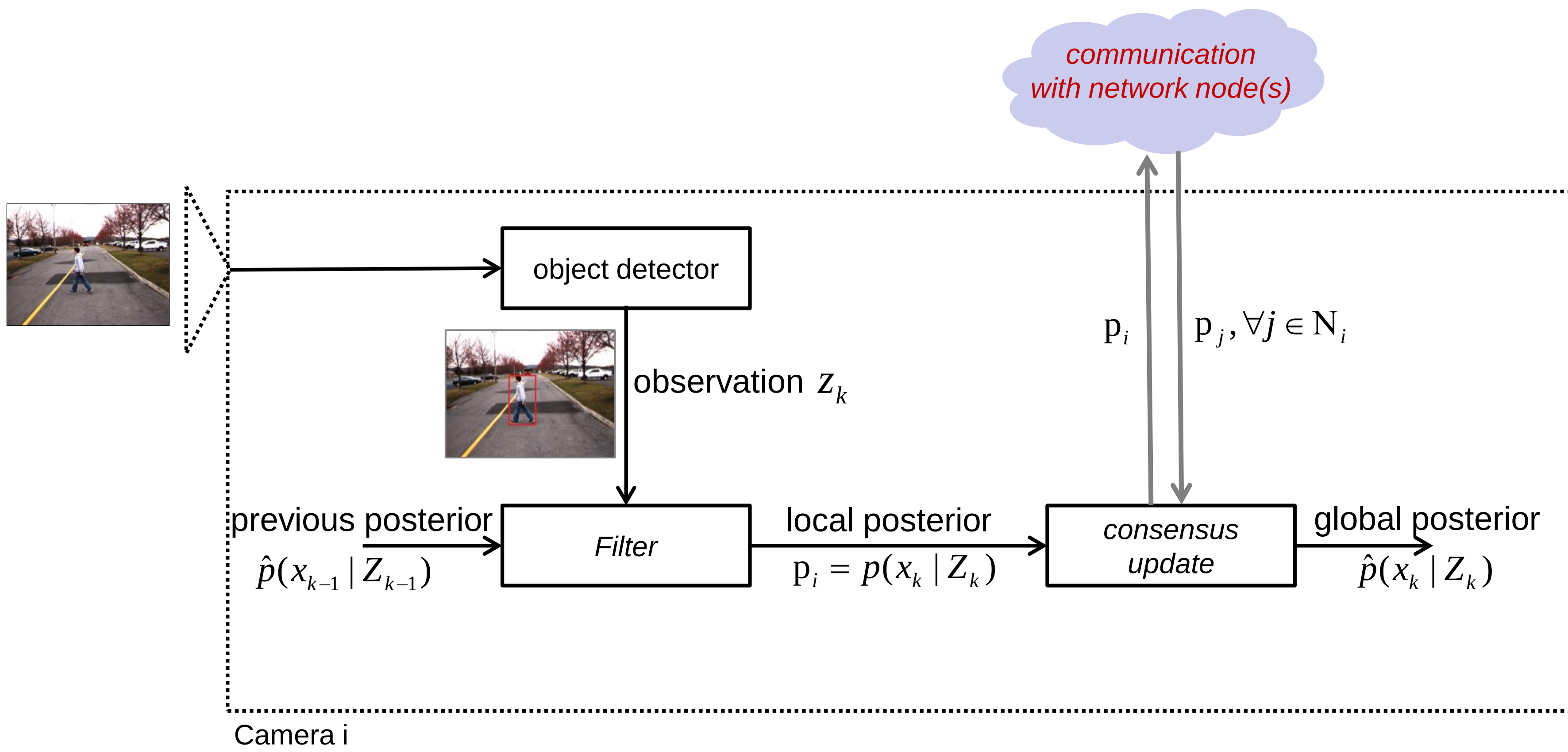
r_c : communication range
r_v : viewing range

Consensus-based fusion

- Objective
  - the same target state estimate at <u>all nodes</u>

- Consensus update: two steps
  - information exchange
    - target state
  - local computation
    - <u>weighted</u> sum

Consensus-based fusion: block diagram



N_i : communicative neighbourhood of camera i

Problems in state of the art

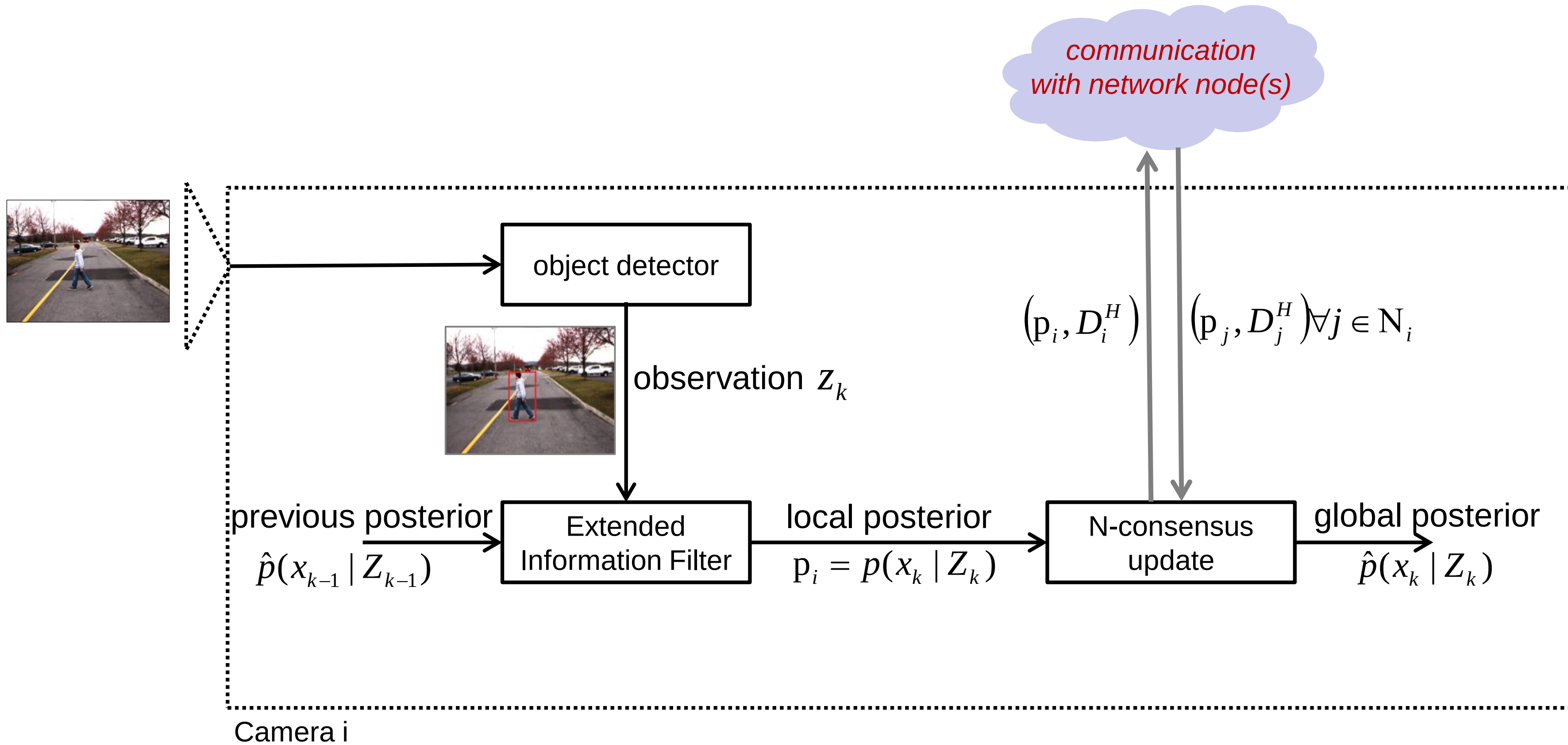
- Average consensus
  - consensus among all nodes
  - weights
    - equal for all nodes
    - depends on communication graph

high resource consumption

- Iterative covariance intersection
  - consensus among all nodes
  - weights
    - not equal for all nodes
    - depends on uncertainty in local estimate

S. Katragadda et al., "Consensus protocols for distributed tracking in wireless camera networks", FUSION, 2014
O. Hlinka et al., "Distributed data fusion using iterative covariance intersection", ICASSP, 2014

Proposed approach: N-consensus



N_i : communicative neighbourhood of camera i

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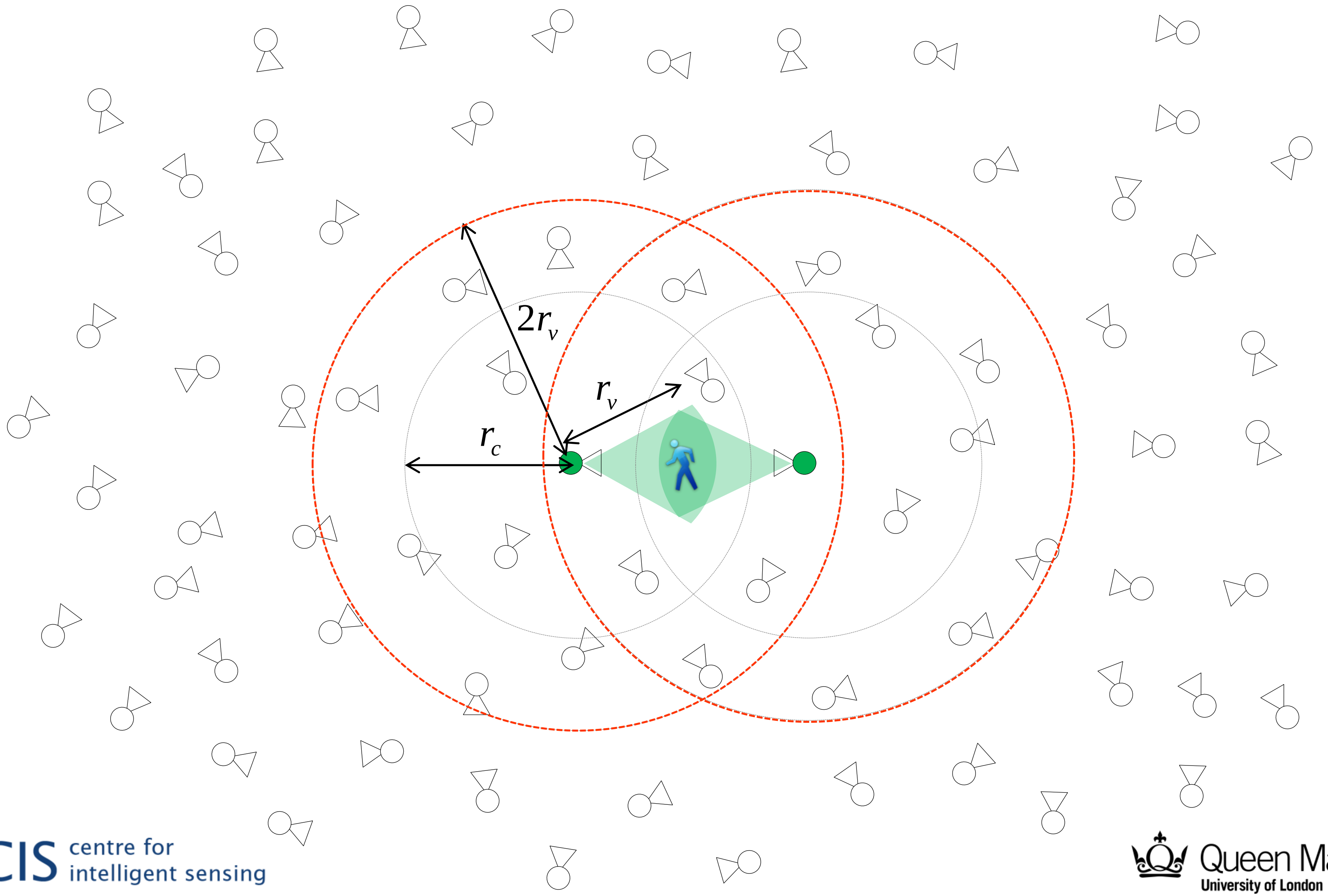
N-consensus: idea

r_c : communication range
r_v : viewing range



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N-consensus

r_c : communication range
r_v : viewing range

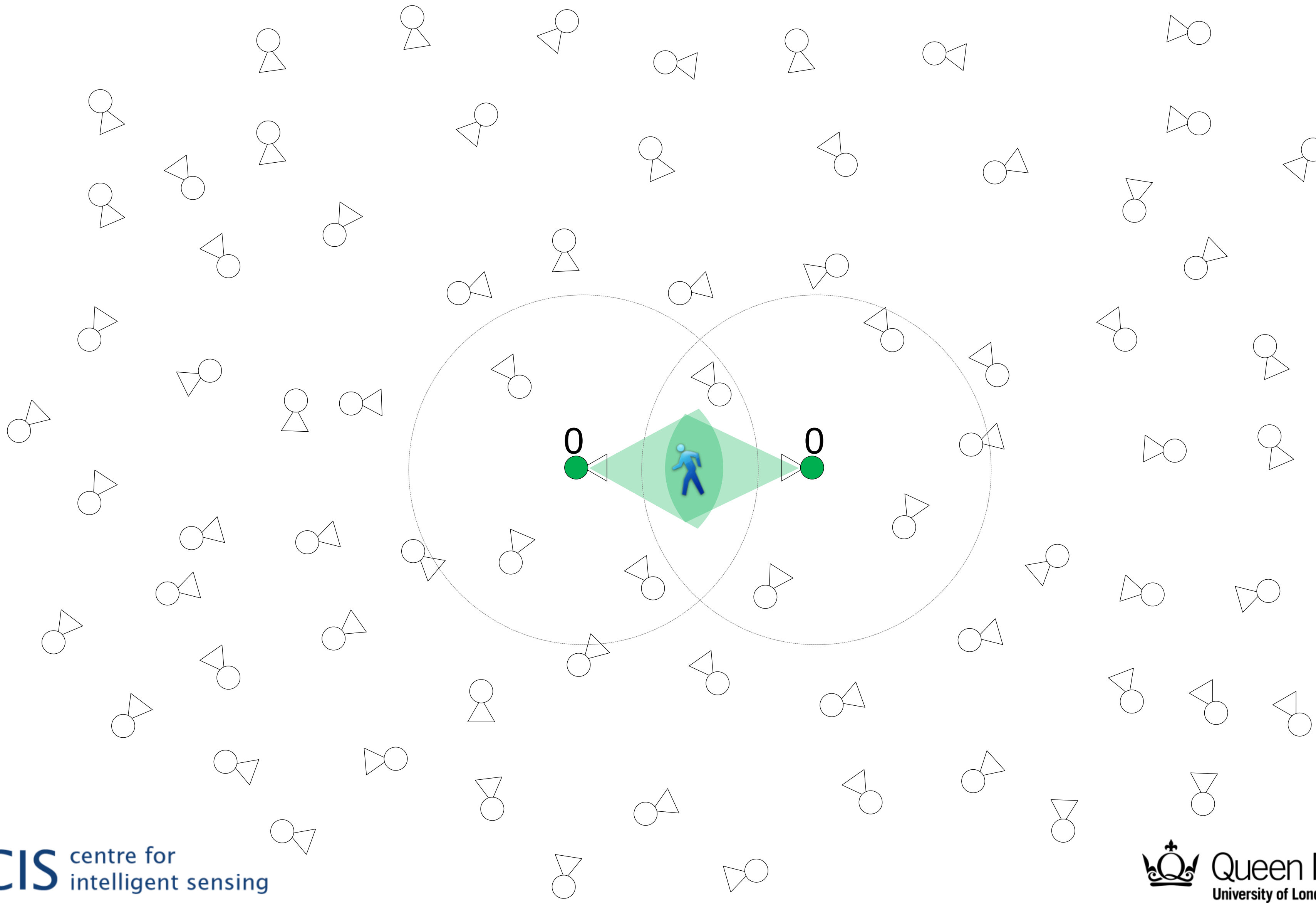
- *D:* maximum possible hop distance between two viewing nodes

$$\boxed{D = \left\lceil \frac{2r_v}{r_c} \right\rceil}$$

- Objective: the same target state at {0,1,.., D}-hop neighbours
  - all "current" viewing nodes
    - for fusion
  - possible "future" viewing nodes
    - for handover

N-consensus: idea

E.g. when $D = 2$



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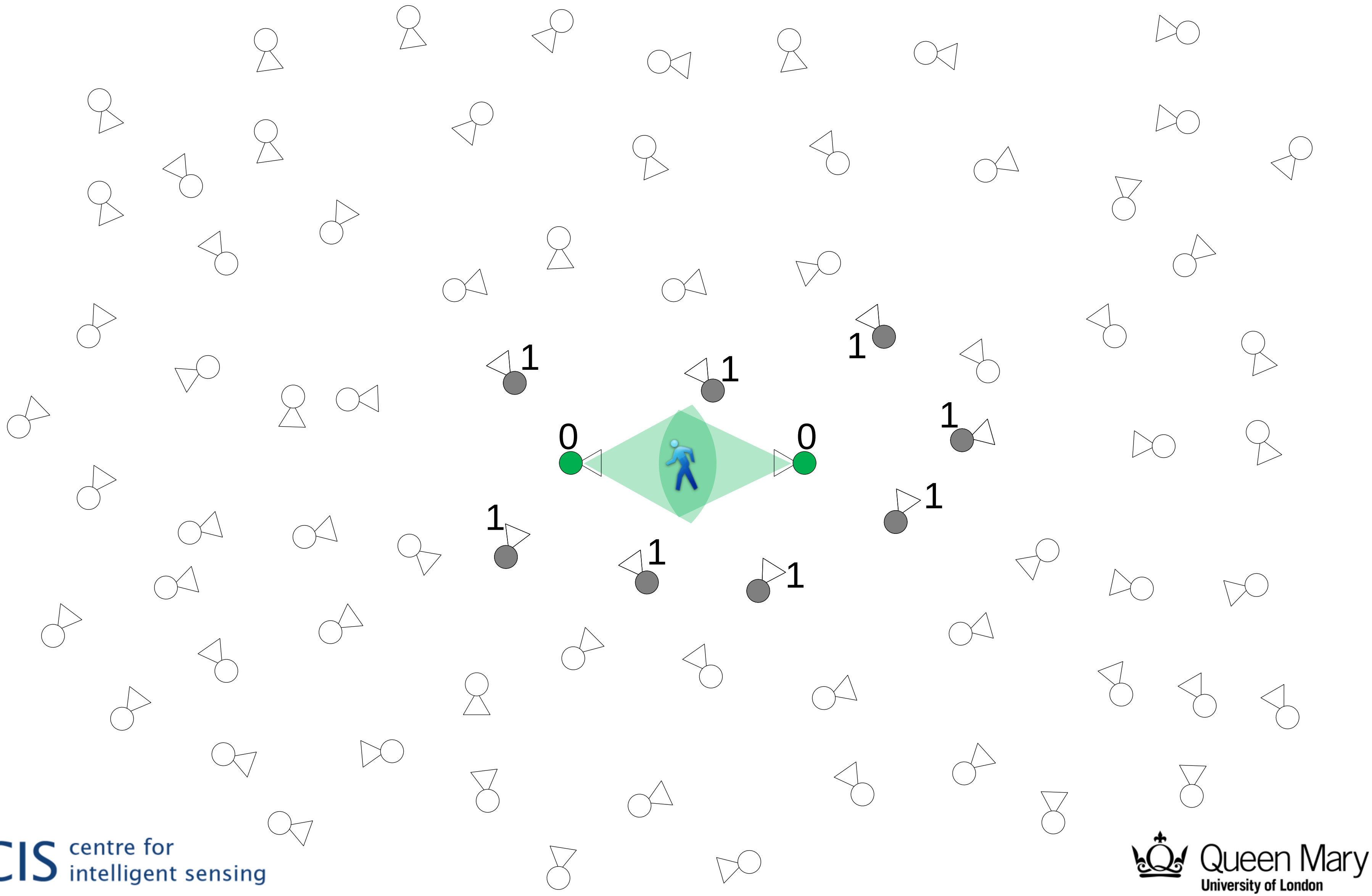
N-consensus: idea

E.g. when $D = 2$



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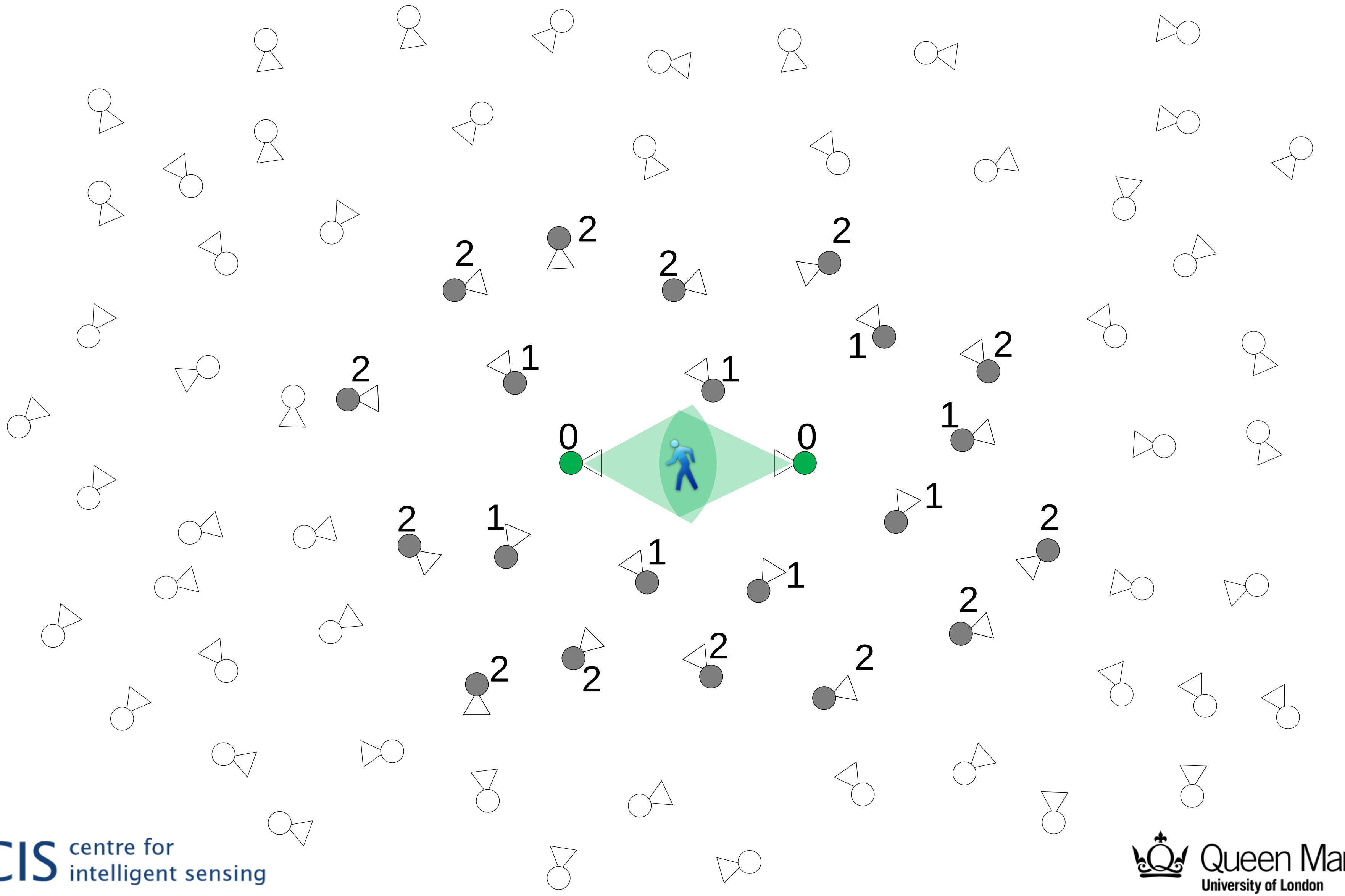
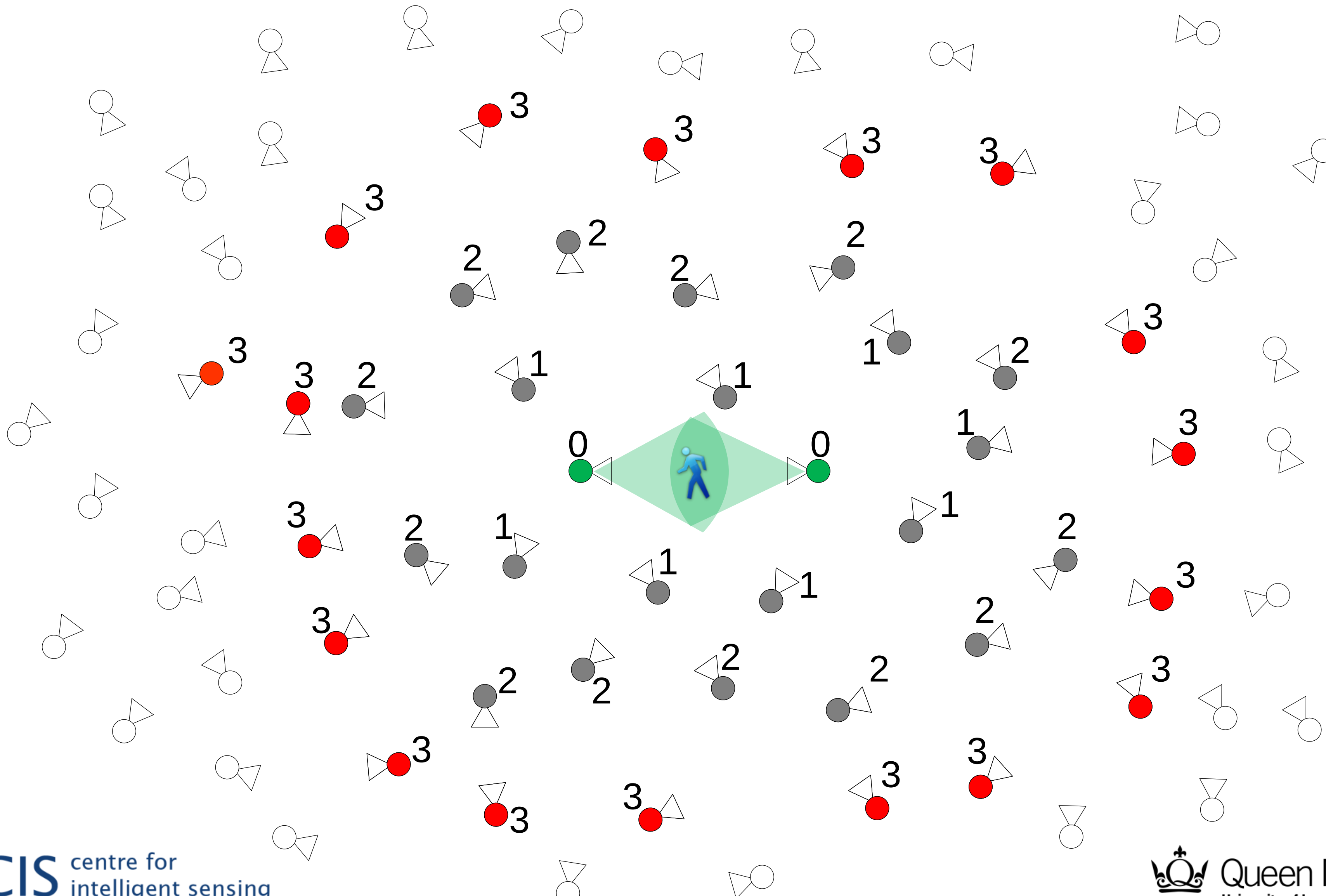
N-consensus: idea

E.g. when $D = 2$



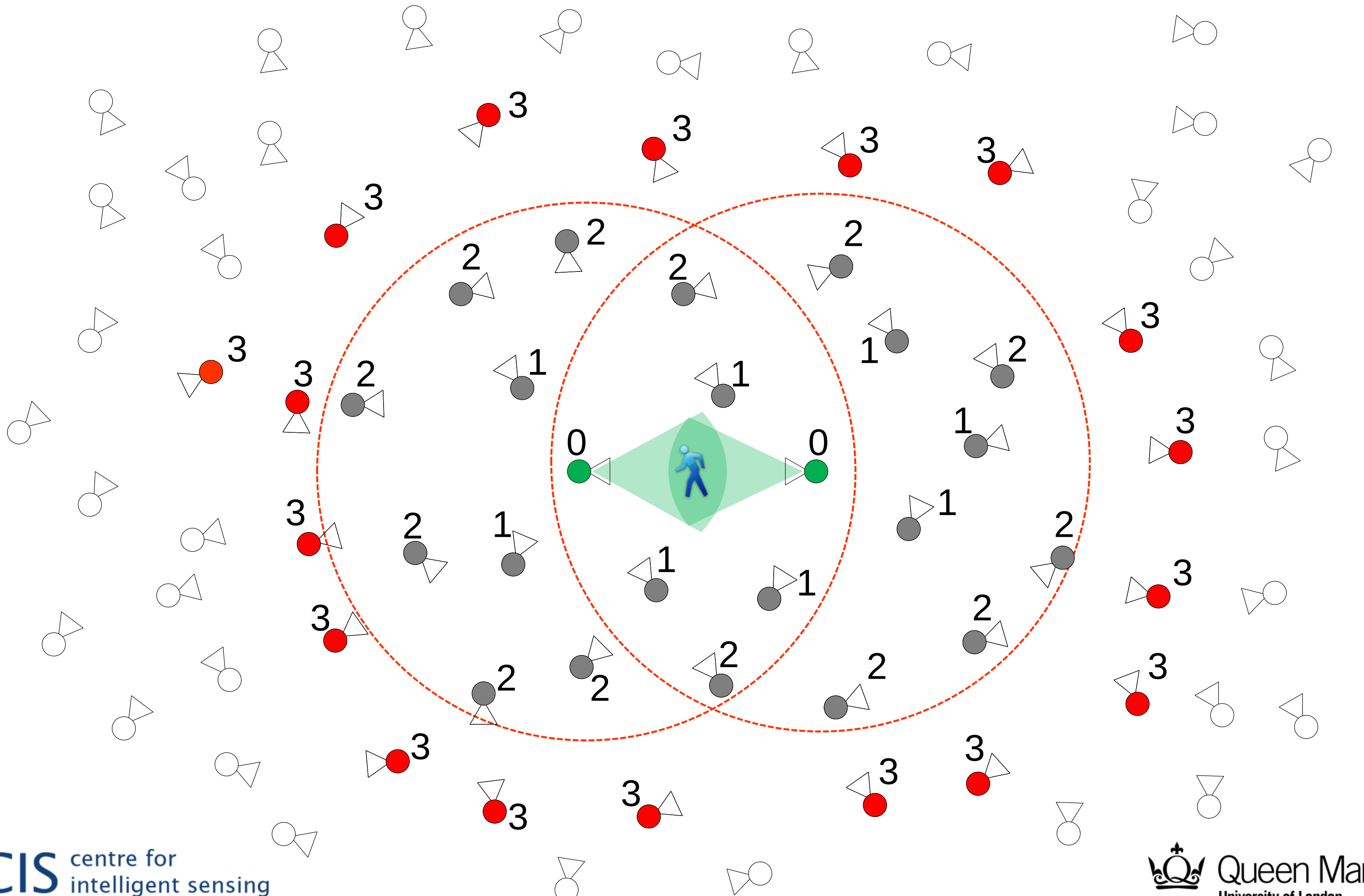
N-consensus: idea

E.g. when $D = 2$



N-consensus: idea

E.g. when $D = 2$



N-consensus update

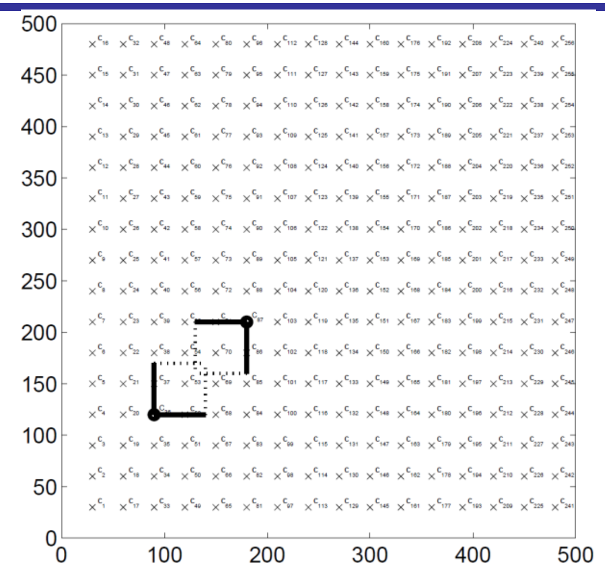
- Information exchange
  - local posterior p_i
    - $\mathrm{p}_i = \mathbf{0}$ for non-viewing nodes
  - proposal hop-distance D_i^H
    - $D_i^H = 0$ for viewing nodes

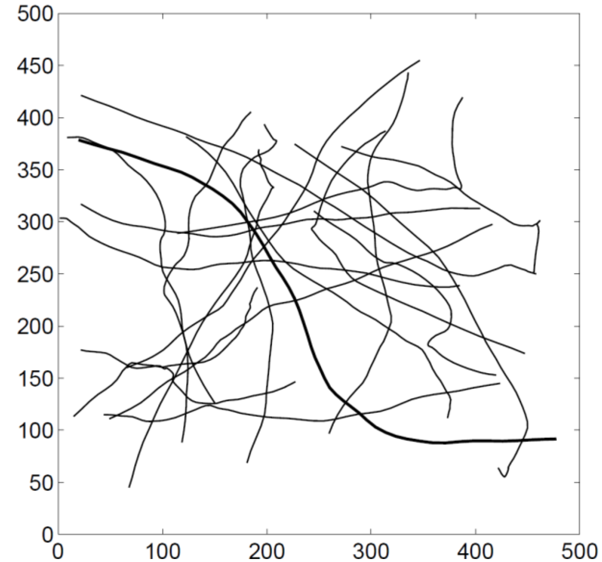
- Local computation
  - weights based on uncertainty in local estimate
  - update hop-distance
    - to minimum of (received hop-distances + 1)

Experimental setup

r_c : communication range
r_v : viewing range

- Motion model
  - non-linear trajectories under Gaussian noise
- Measurement model
  - homography-based non-linear model
  - $r_v = 50m$
- Two cases: $r_c < r_v$; $r_c > 2r_v$
- Performance measures
  - mean tracking error
  - communication cost





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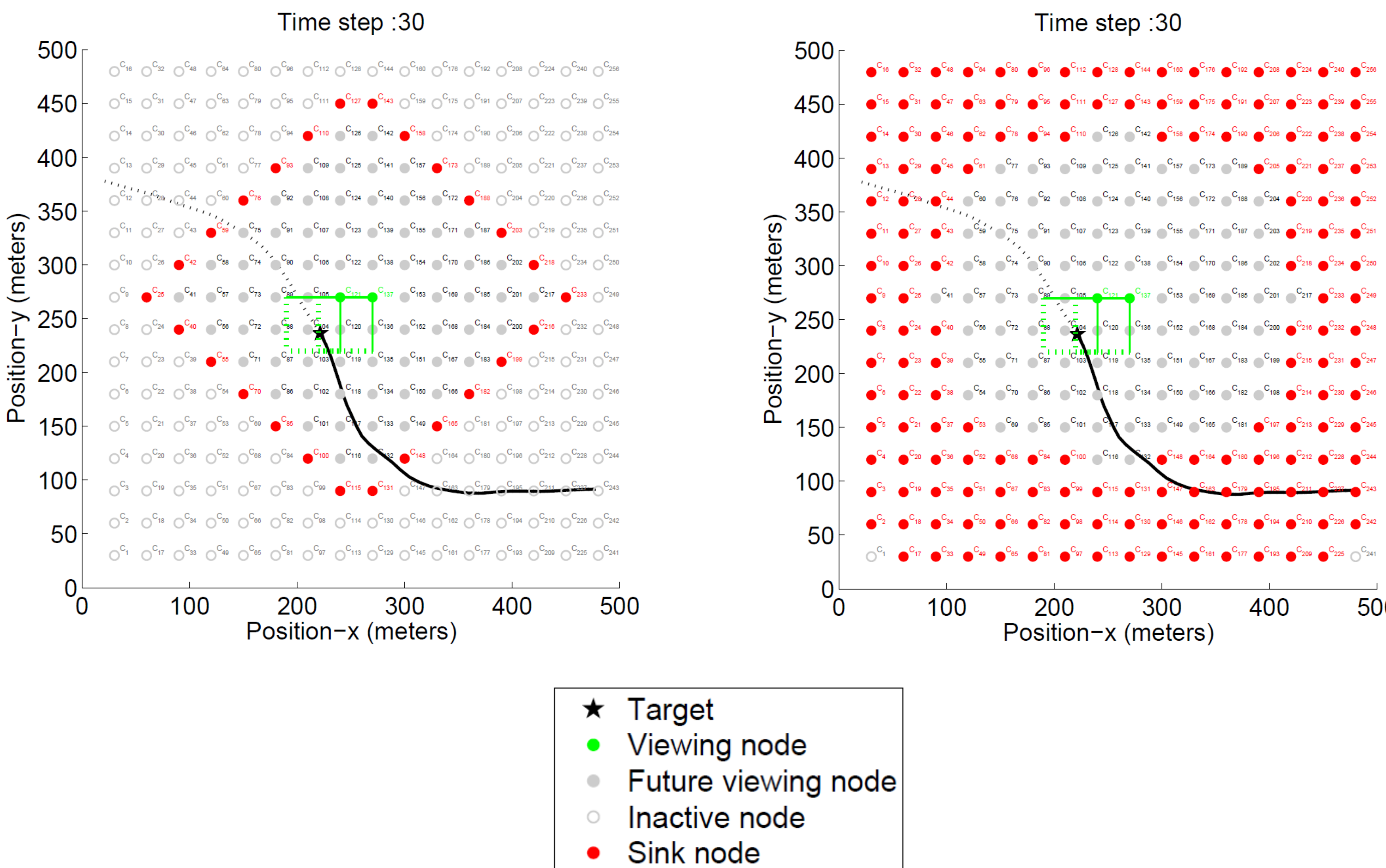
N-Nodes

$r_c = 30m$ $r_c = 150m$



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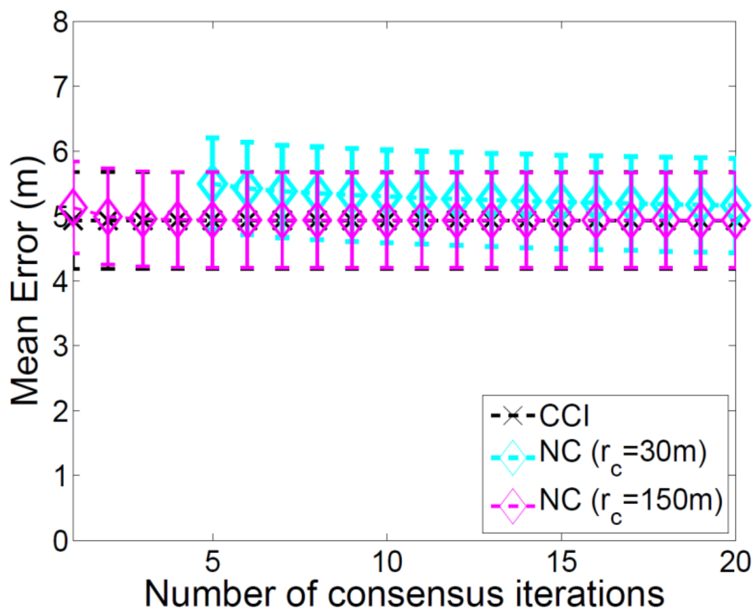
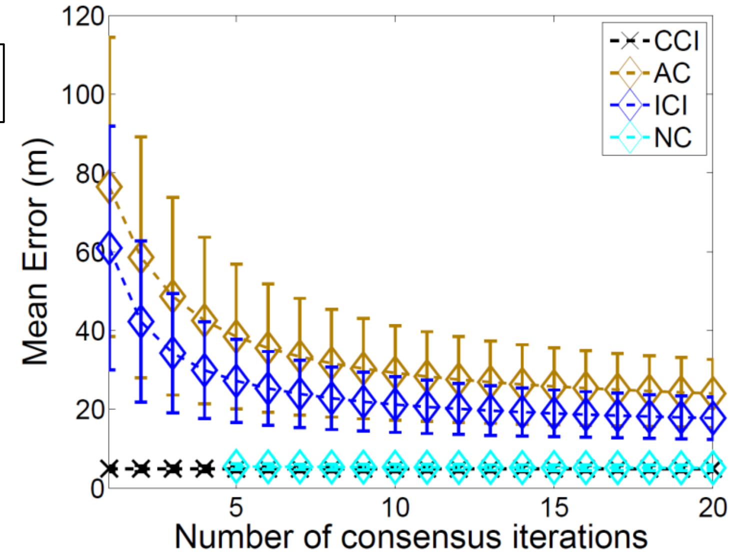
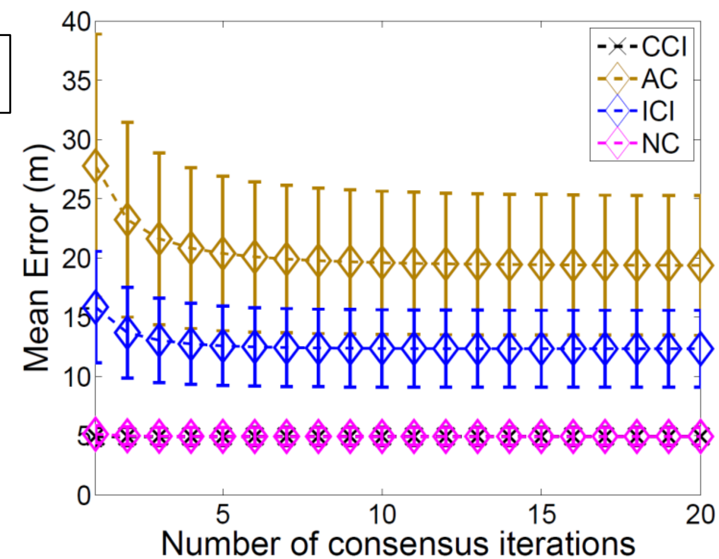
Accuracy



$r_c = 30m$

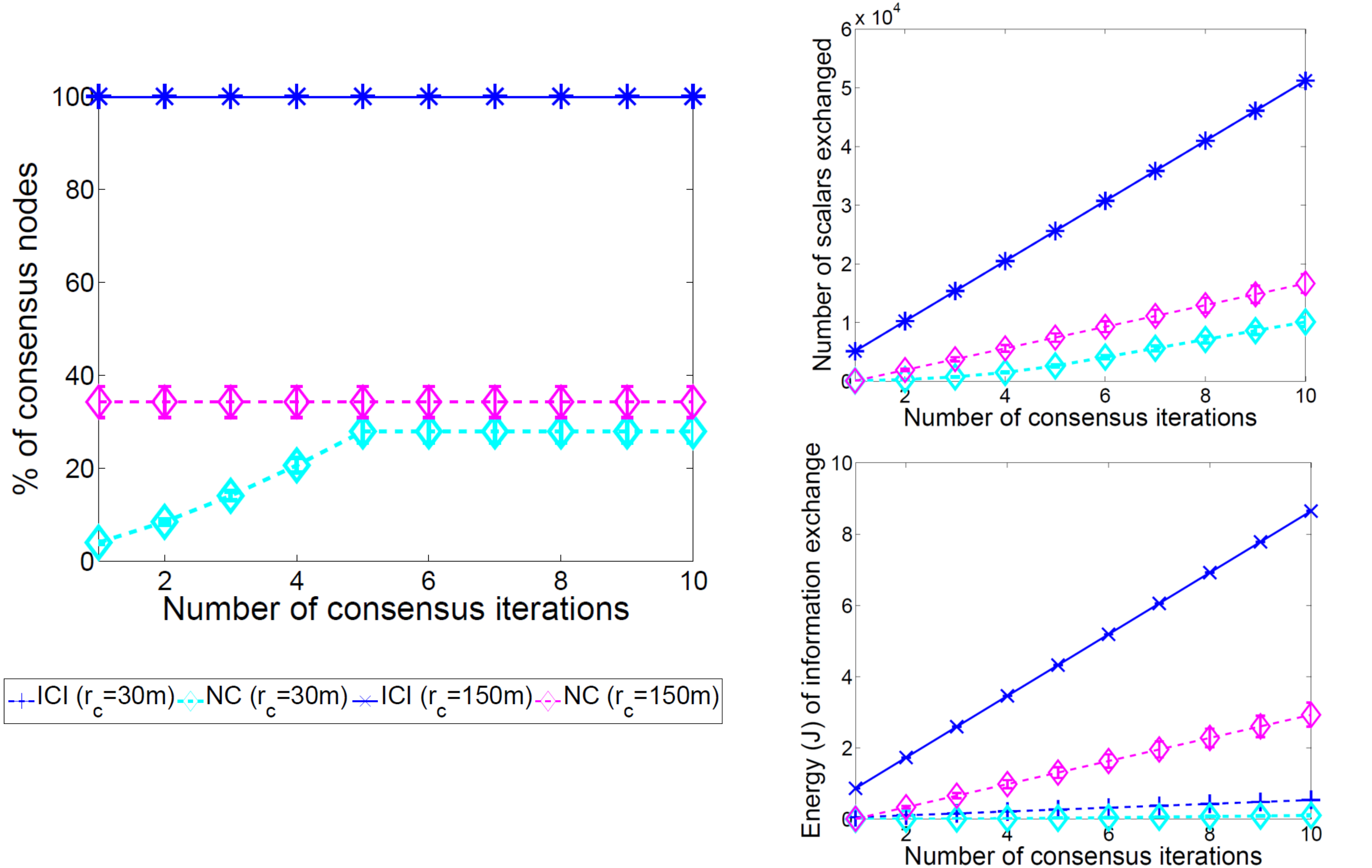


$r_c = 150m$



CCI: Centralised covariance intersection
AC: Average consensus
ICI: Iterative covariance intersection
NC: Neighbour consensus

Communication cost



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Conclusions

- N-consensus
  - neighbourhood identification using limited hop-count search
  - consensus within the neighbourhood
  - improved accuracy, reduced communication cost

Source code: www.eecs.qmul.ac.uk/~andrea/software.htm

- Future work
  - relax the assumption on “homogeneous” cameras
    - viewing range (r_v) is not the same for all cameras
  - neighbourhood identification using vision graph