WiSE-MNet: an experimental environment for wireless multimedia sensor networks

Christian Nastasi
c.nastasi@sssup.it

Andrea Cavallaro
andrea.cavallaro@eecs.qmul.ac.uk

www.eecs.qmul.ac.uk/~andrea/wise-mnet.html

WMSNs: context

- Wireless Multimedia Sensor Networks (WMSNs)
  - Evolution of WSNs to more complex (vectorial) data - e.g. audio, video
  - Several challenges
    - high network scalability
    - resource-constrained devices
    - raw data cannot be (generally) transferred
    - local processing is required (but it is much more complex than in WSNs)
  - Multi-disciplinary problem
    - networking
    - sensor signal processing
    - embedded system design

Need a simulation environment for WMSNs!

Network simulators

- Several existing network simulators
  - NS-2
  - OPNET
  - TrueTime
  - OMNeT++

- What are we looking for?
  - Configurability (e.g. scripting languages, configuration interfaces)
  - Support for standard and state-of-the-art communication protocols
  - Extensibility
  - Programming language

NS-2: a popular open-source network simulator

- Modules written in C++
- Simulation interface based on O-Tcl
- Originally designed for TCP/IP computer networks
  - Extensions to support wireless network (external contribution)
  - Integration of wireless and wired networks not simple
  - Mobility requires extensions
- Network stacks
  - generally much more complex than WSN's stacks
- Maintainability and extensibility are difficult

http://www.isi.edu/nsnam/ns/

OPNET: a commercial network simulation software

- Modules written in C++
- GUI for simulation
  scenarios and network models
- Three levels of configurability
  - Network level
    - defines topology
  - Node level
    - defines node behaviour and data flow
  - Process level
    - defines protocols' logic through finite state machine formalism

http://www.opnet.com/

TrueTime: a Matlab/Simulink toolbox

- Mainly for control applications
  - to simulate (distributed) control
- Node behaviour in Matlab/Simulink
- Configuration through Simulink
- Simple networking models
  - including IEEE 802.15.4
- Integration with Matlab-based software is straightforward

http://www3.control.lth.se/truetime/

OMNeT++: open-source (generic) network simulator

- Generic discrete-event simulation engine
- Generic modules interactions can be defined
  - behaviour is coded in C++
  - interconnections/composition specified through a Network Description (NED) language
  - parameters can be set through configuration files
- Highly flexible and extensible with external libraries
- Network elements
  - nodes, protocols, channels
  - provided (externally) as simulation models (INET, MiXiM, Castalia)

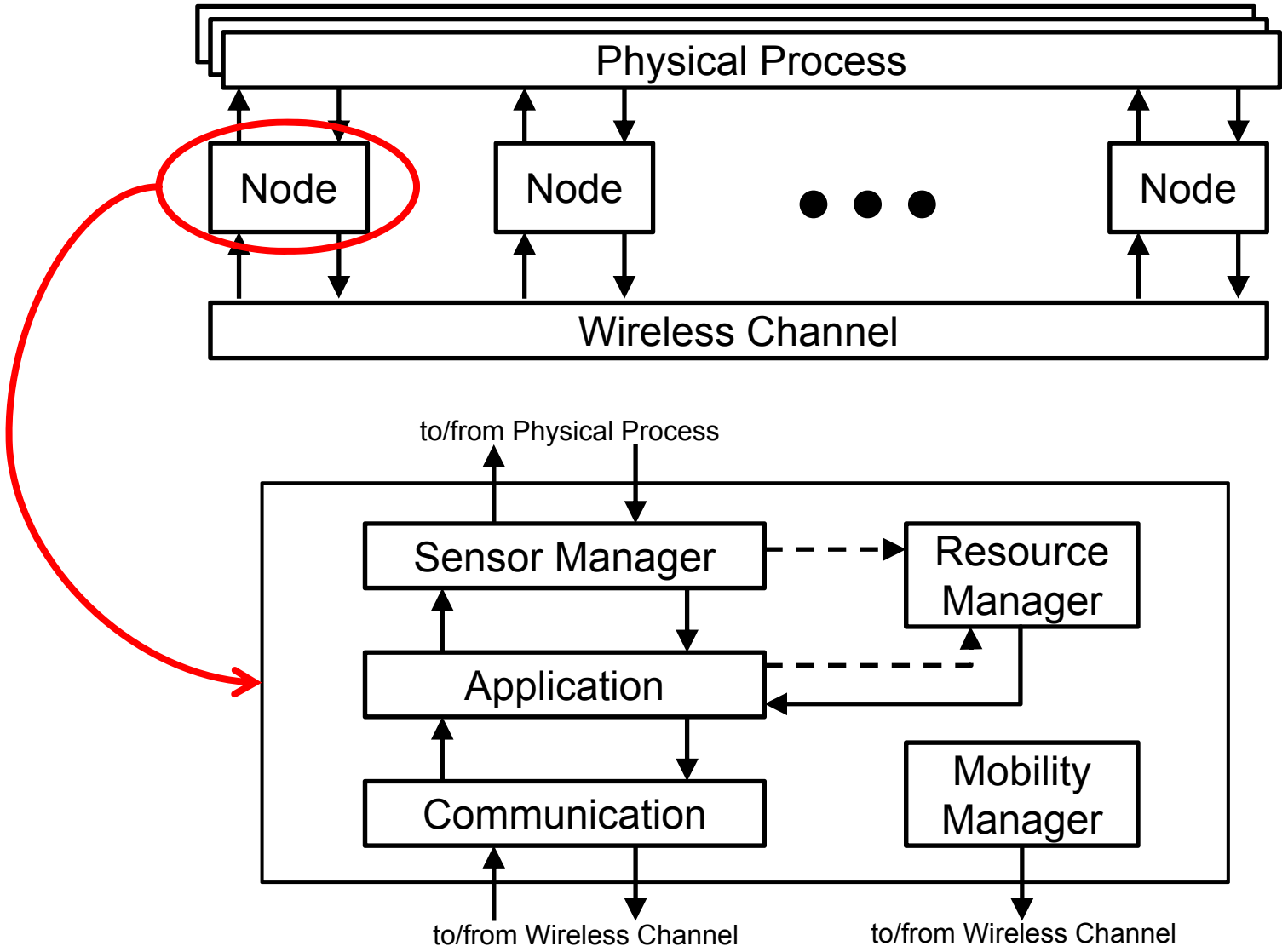
http://www.omnetpp.org/

Which simulation model?

- Simulation Model: *Castalia*
  - Designed to model distributed algorithm for WSNs
  - Realistic wireless channel and radio models
  - Physical process (real-world events) and sensing model
  - Node Mobility
  - Resource management (e.g. CPU, battery)

http://castalia.npc.nicta.com.au/

Castalia simulation model

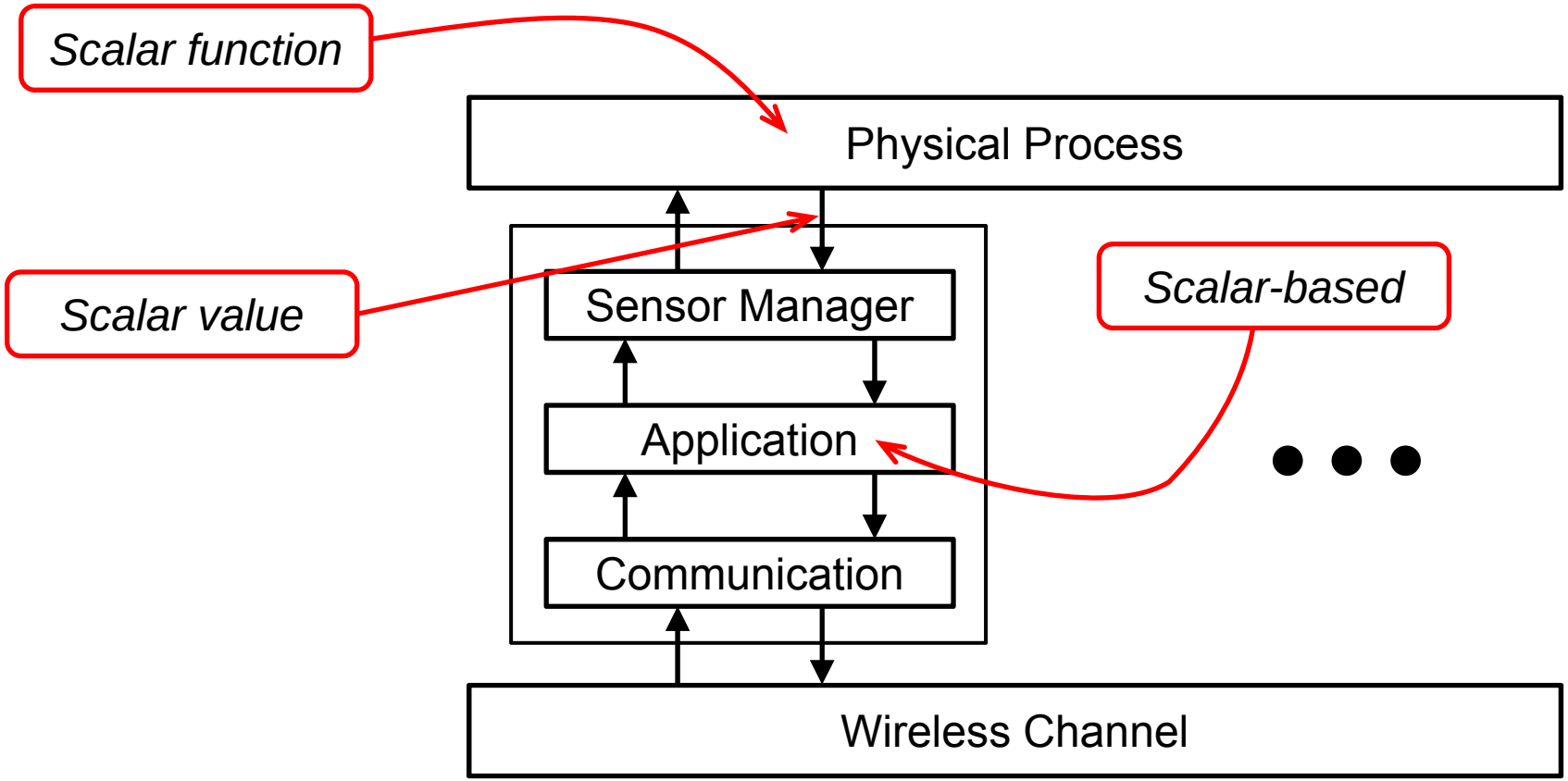


Proposed extensions to the Castalia model

- Generalization of the sensor data-type
  - from scalar-based to any data type
- Idealistic communication & direct application communication
- Specific modules
  - moving target
  - simple camera modelling
  - target tracking application
- Simple GUI
  - for 2D world representation

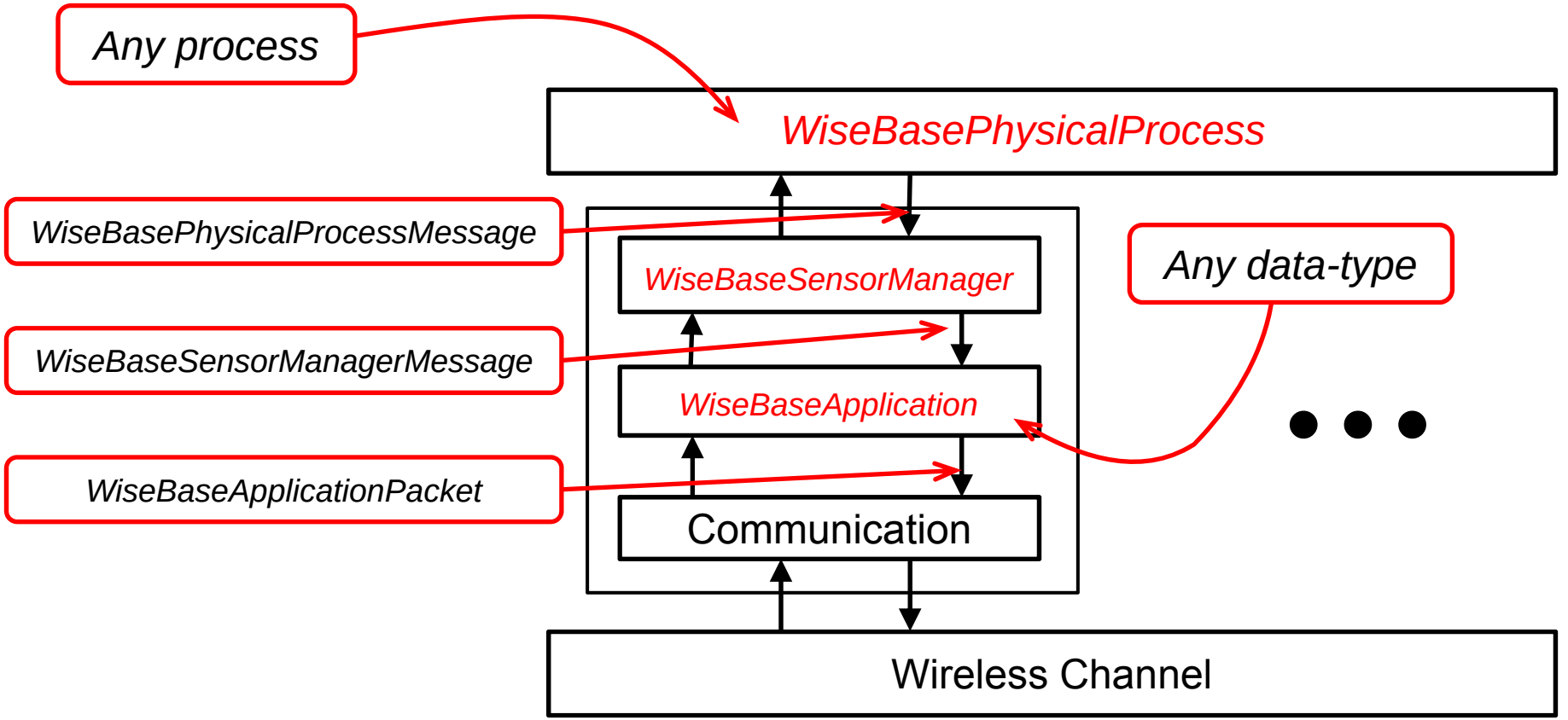
Generalized data-types

Castalia supports only scalar-based applications



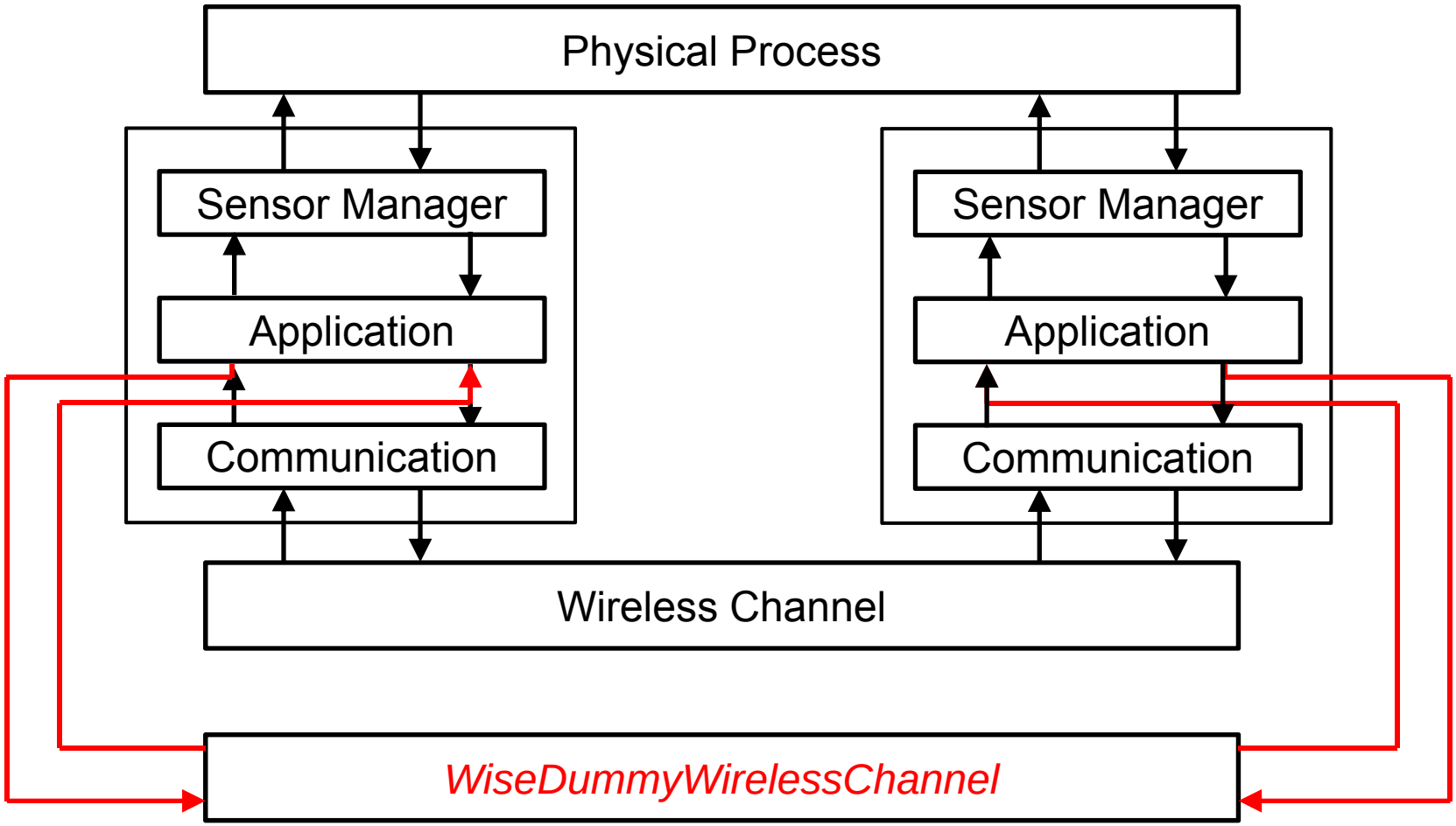
Generalized data-types

We want to have any possible data-type: object-oriented approach



Idealistic communication

Seemingly from the application point of view: bypass communication



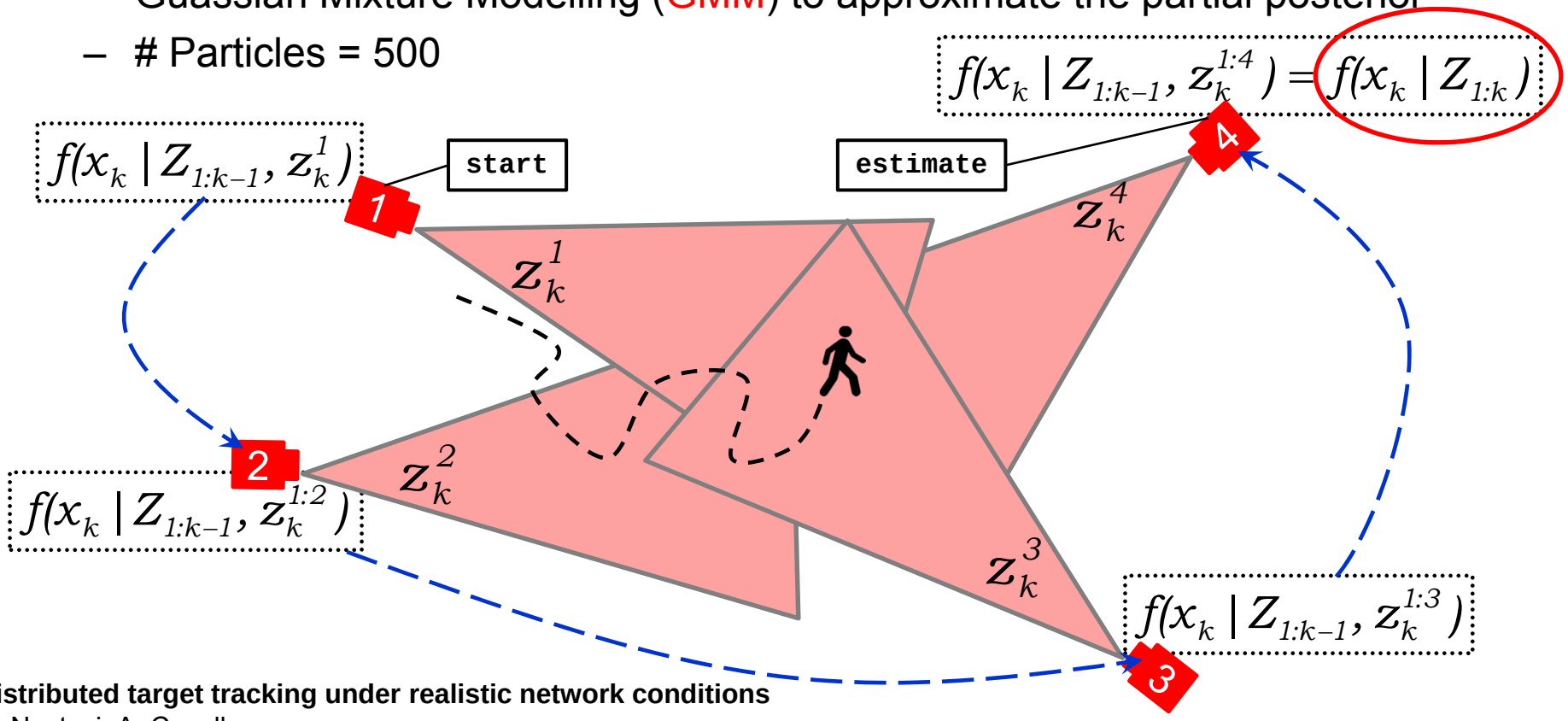
New specific modules

- *WiseMovingTarget* - physical process
  - moving target on a ground plane
  - different types of motion: e.g. linear, circular, random
  - target represented as a box
- *WiseCameraManager* - sensor manager
  - top-down facing camera
  - object detections produced: bounding boxes
  - can be extended to any FOV, projection model or to use real-world images
- *WiseCameraApplication* - application layer
  - hierarchy of modules implementing a distributed tracking algorithm

Simulation example

Tracking algorithm

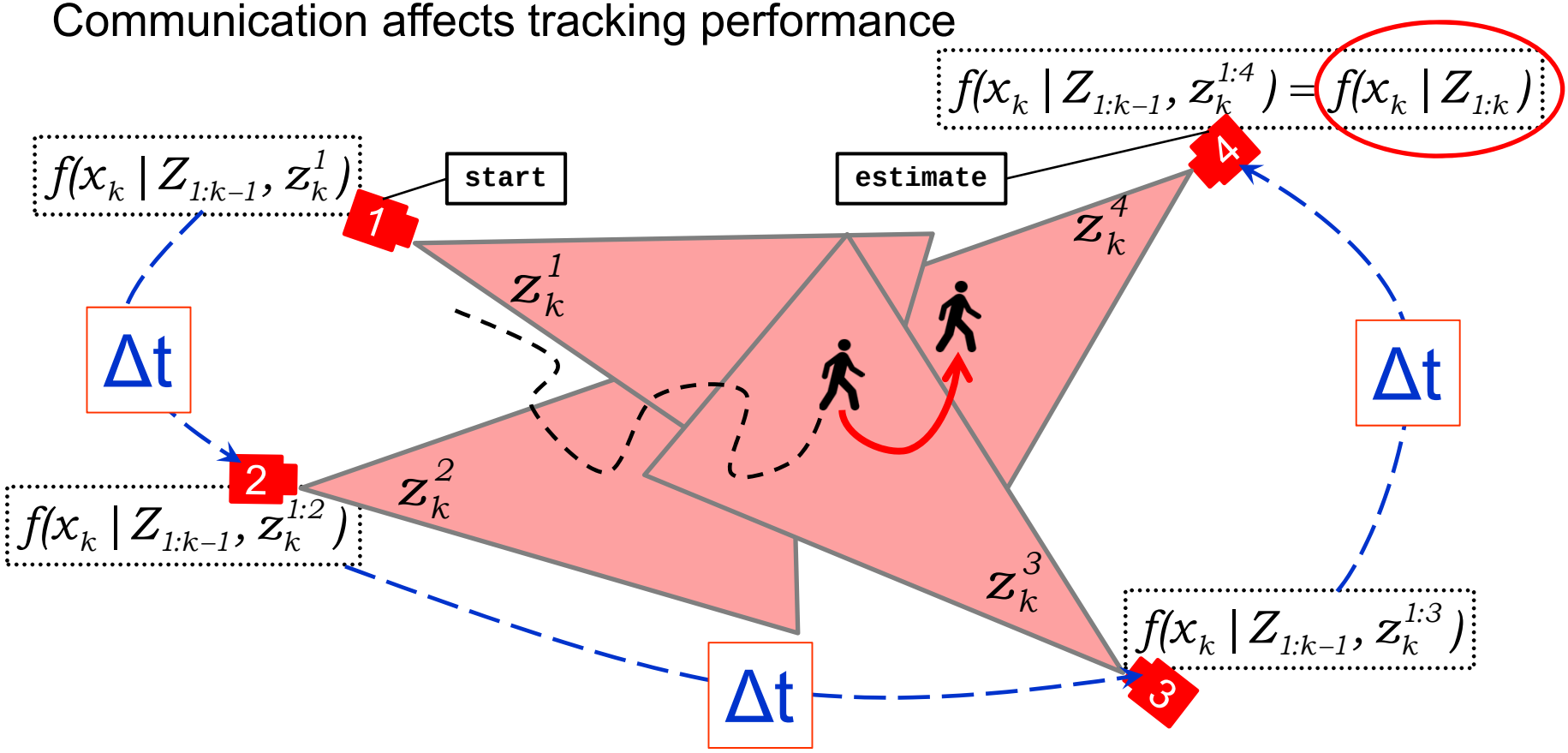
- Distributed Particle Filter (DPF)
- Sequential measurement aggregation through partial posterior exchange
- Guassian Mixture Modelling (GMM) to approximate the partial posterior
- # Particles = 500



Distributed target tracking under realistic network conditions
C. Nastasi, A. Cavallaro
Proc. of Sensor Signal Processing for Defence, London, 28-29 September 2011

Network delay problem

Communication affects tracking performance



Analysis of performance degradation with increased network load

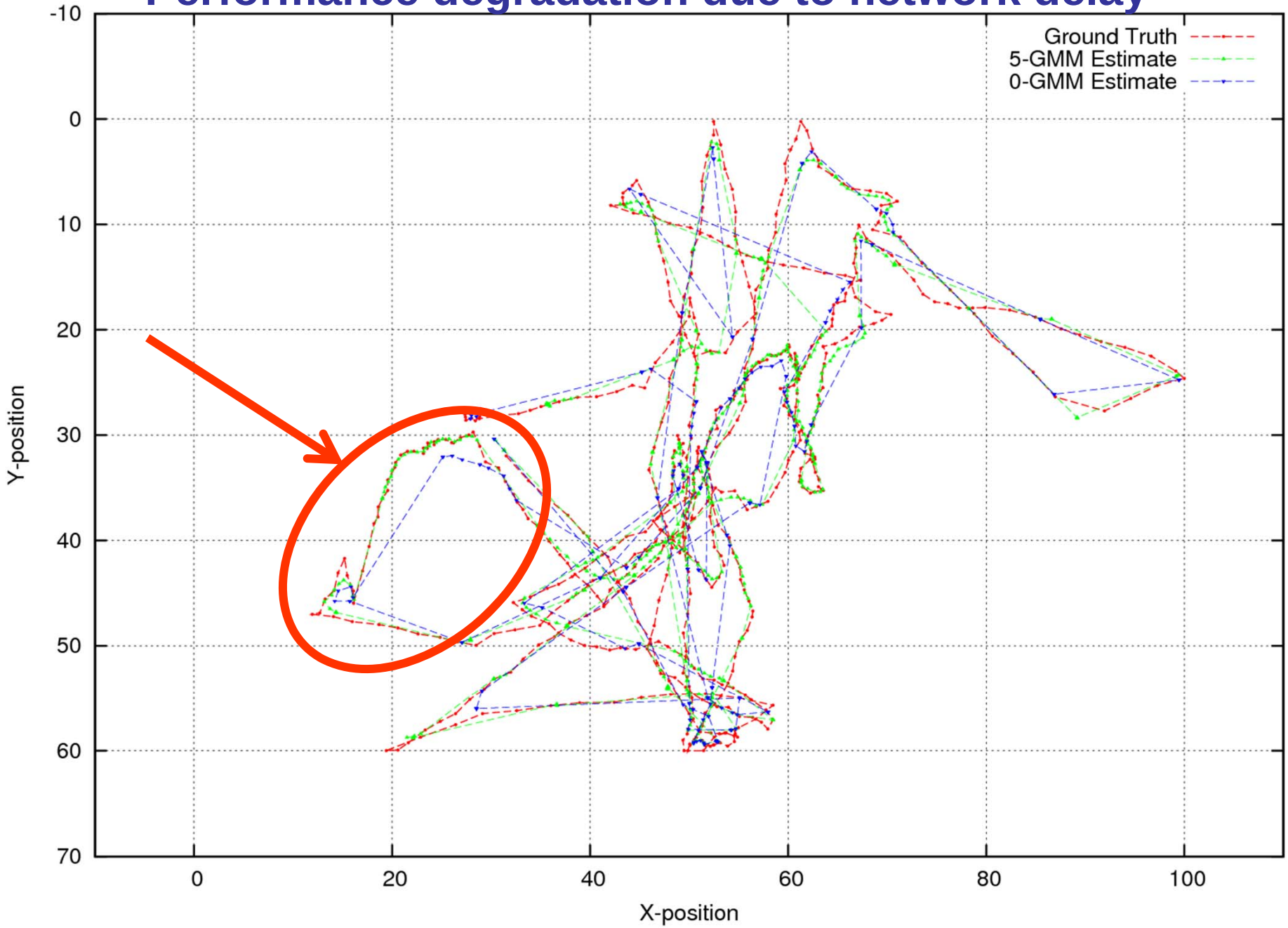
- 0-GMM (exchanging the whole particle set)
- 5-GMM (mixture of 5 Gaussians to approximate the particle set)

Simulation setup

- Network
  - T-MAC protocol, BW = 250 kbps
  - request-to-send/clear-to-send mechanism
  - acknowledged-transmission mechanism
  - number of retransmissions: 10

- Cameras
  - Covering 6000 sqm
  - 500 sensors (random uniform distribution)
  - 6m from the ground plane (top-down facing)
  - Frame Rate = 1fps

Performance degradation due to network delay



Conclusions

- Conclusions
  - Realistic simulation environment for WMSNs
    - Extension of the Castalia/OMNeT++ simulation model
    - Generic data-type support
    - Simplistic world model
  - Application example: distributed target tracking

Simulator available as open source at
www.eecs.qmul.ac.uk/~andrea/wise-mnet.html

- Future work
  - More complex networking conditions
  - Support for real-world images