# Visual Wireless Sensor Networks for Mission-Critical Surveillance Applications: perspectives with mobile robots integration

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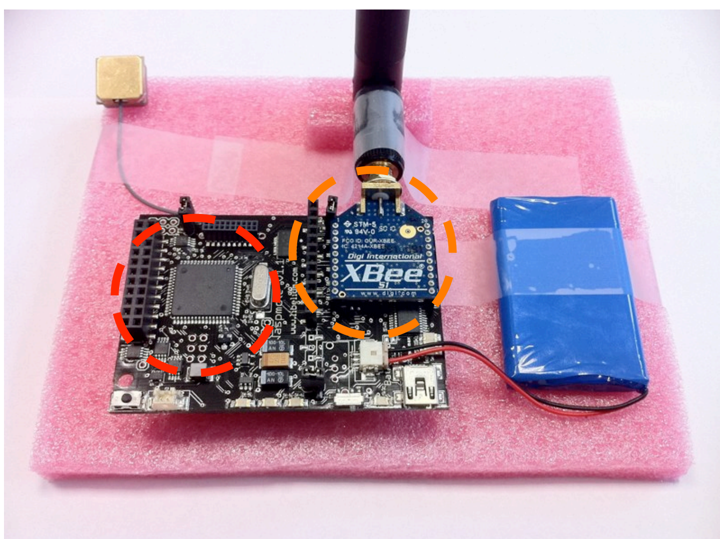
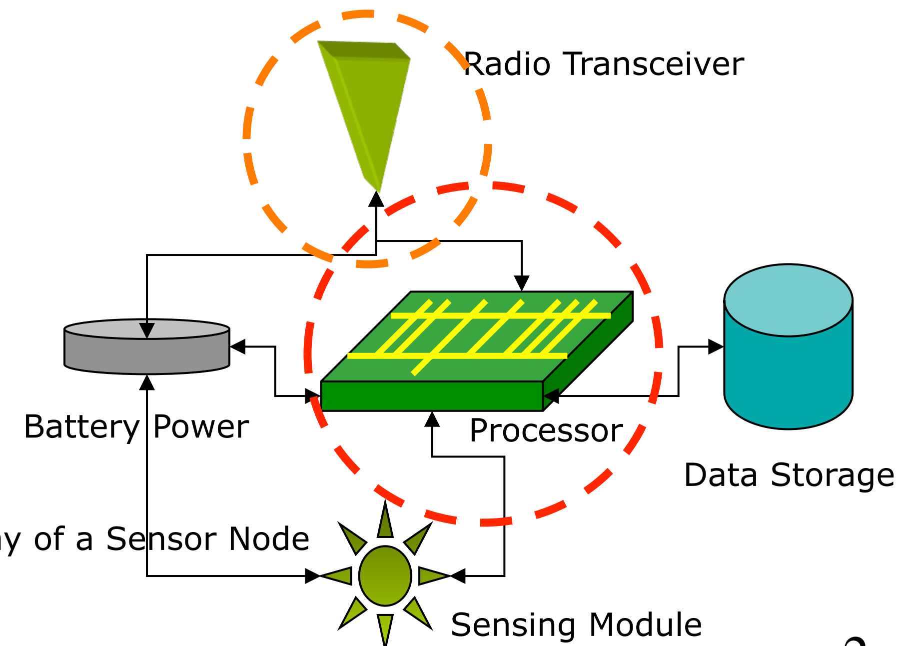
# Wireless autonomous sensor

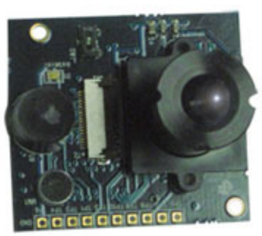
- In general: low cost, low power (the battery may not be replaceable), small size, prone to failure, possibly disposable
- Role: sensing, **data processing**, communication



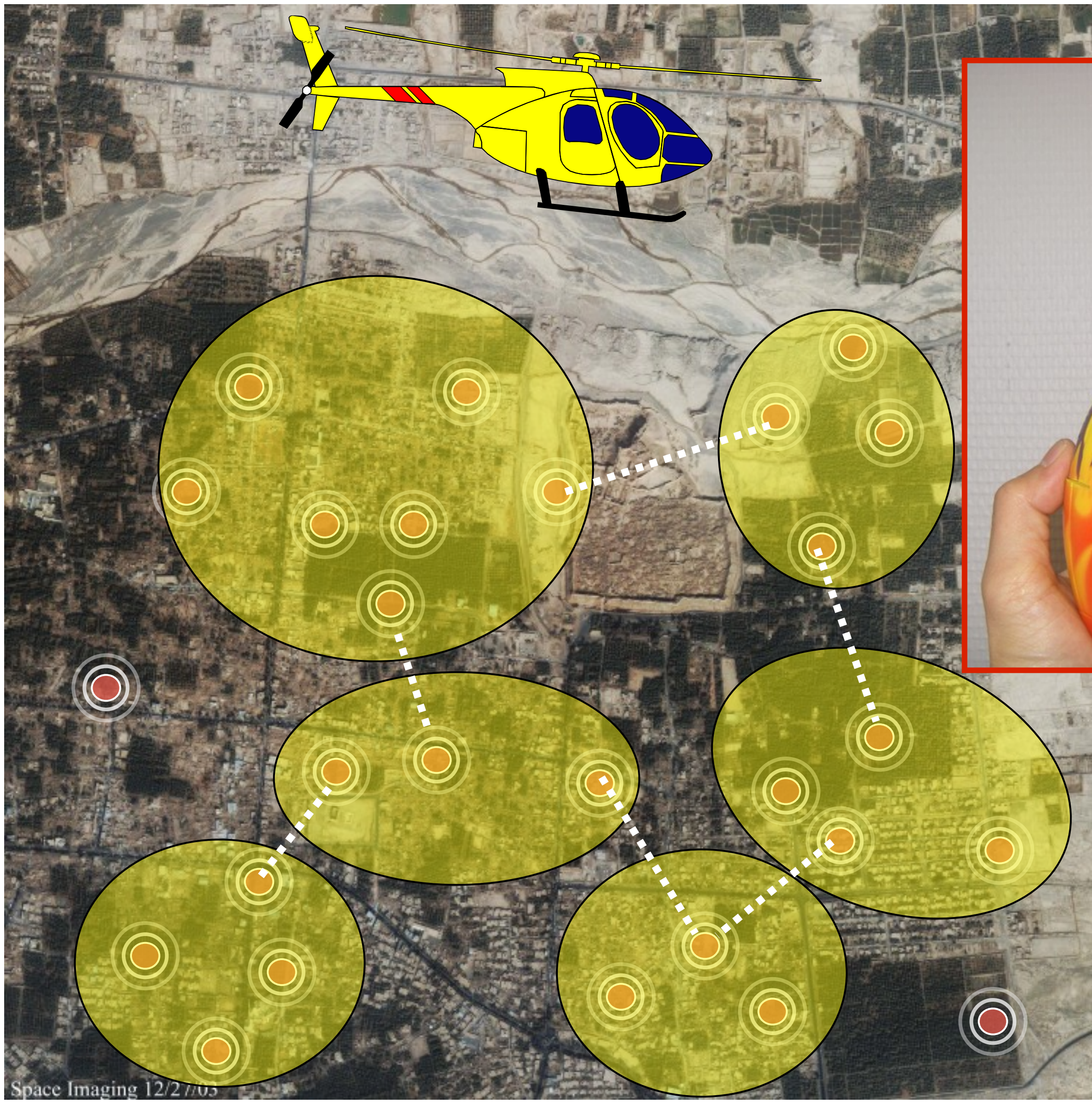


# Search&Rescue, security

Imote2



Multimedia
board




# Don't miss important events!

Whole understanding of the scene is wrong!!!

What is captured

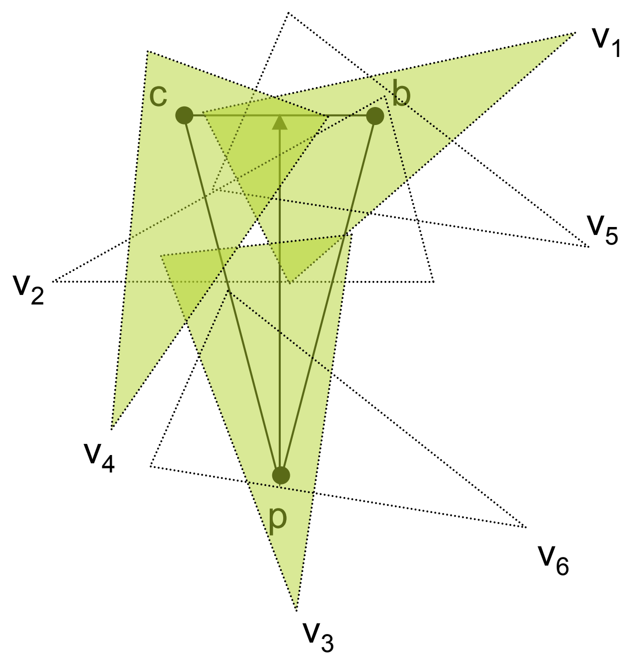
# How to meet surveillance app's criticality

- Capture speed can be a « quality » parameter
- Capture speed for node V should depend on the app's criticality and on the level of redundancy for node V
- V's capture speed can increase when as V has more nodes covering its own FoV - cover set

# Node's cover set

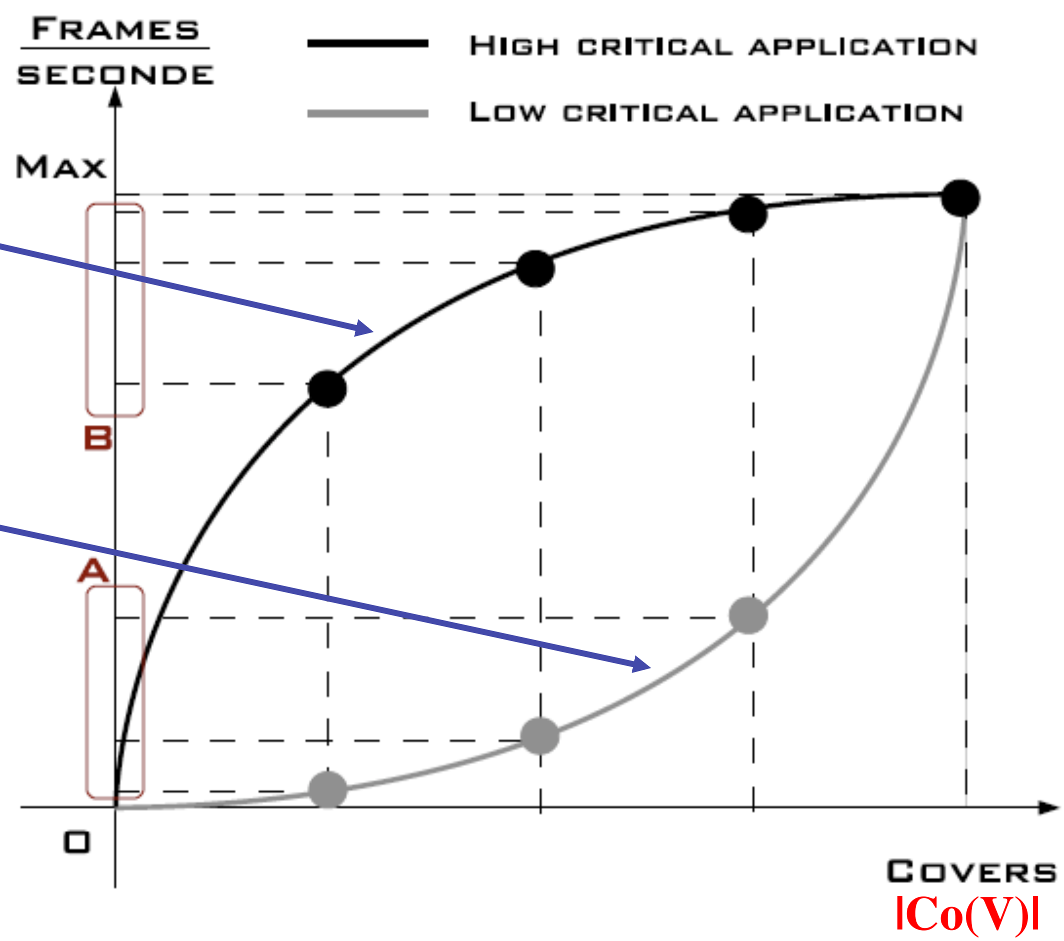
$Co(V) = \{$
$\{V\},$
$\{V_1, V_3, V_4\},$
$\{V_2, V_3, V_4\},$
$\{V_3, V_4, V_5\},$
$\{V_1, V_4, V_6\},$
$\{V_2, V_4, V_6\},$
$\{V_4, V_5, V_6\}$
$\}$

$|Co(V)| = 7$



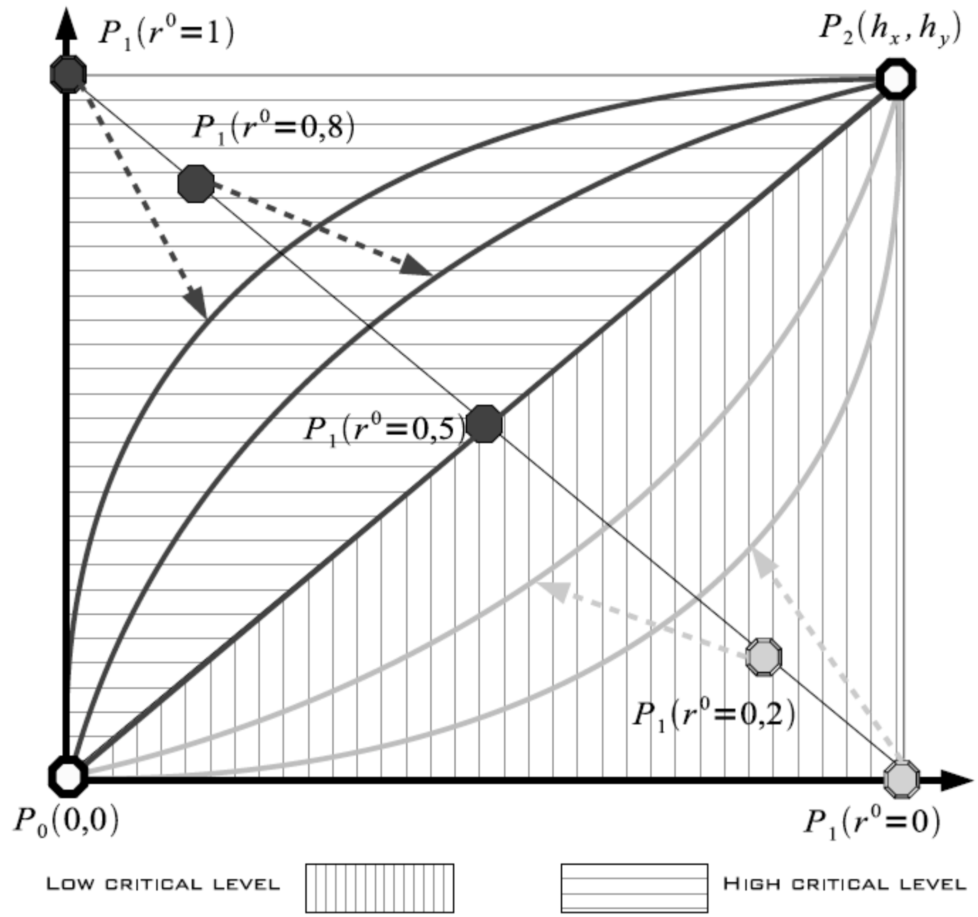
# Criticality model (1)

- Link the capture rate to the size of the cover set
- High criticality
  - Convex shape
  - Most projections of X are close to the max capture speed
- Low criticality
  - Concave shape
  - Most projections of X are close to the min capture speed
- Concave and convex shapes automatically define sentry nodes in the network



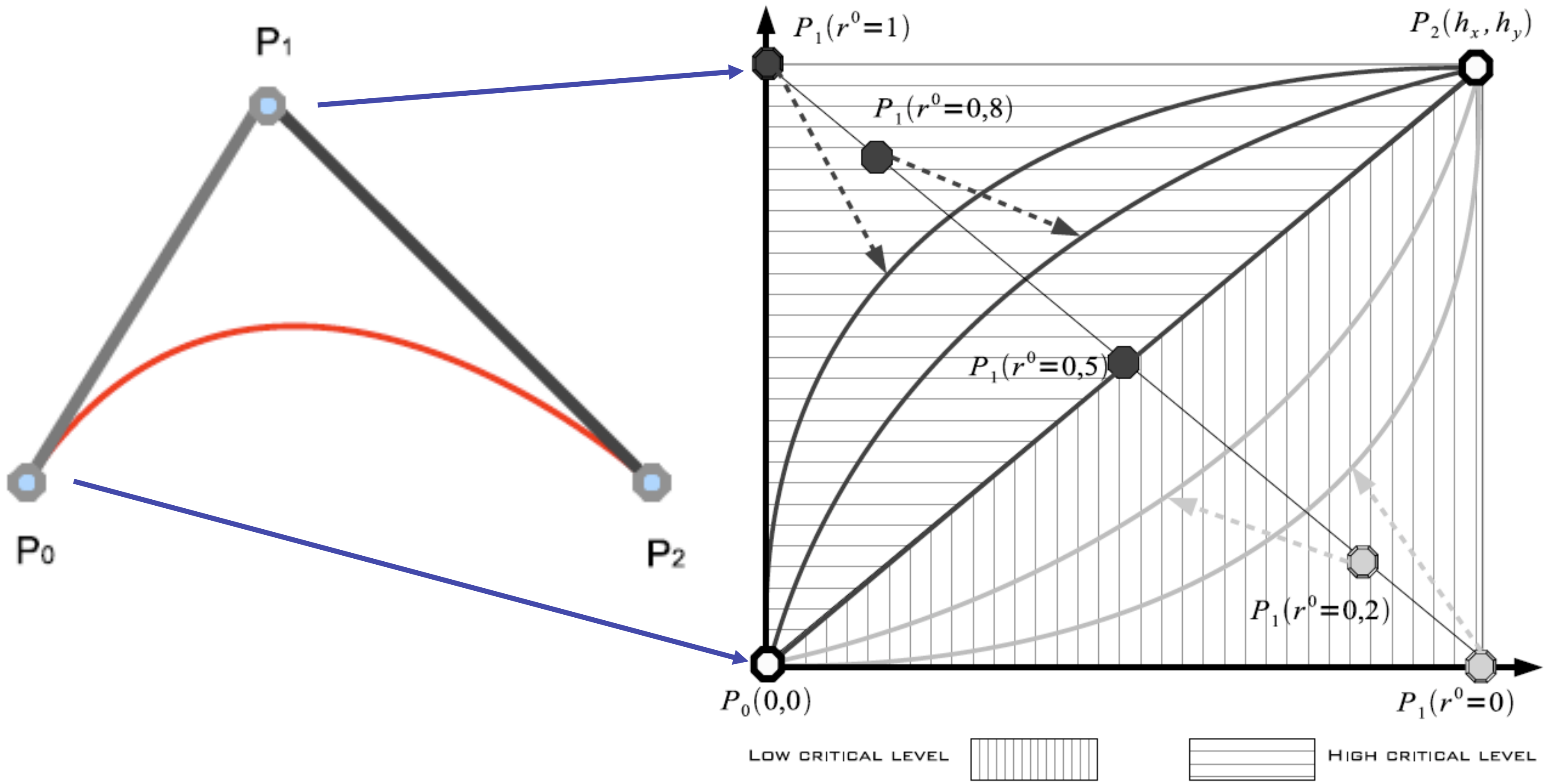
# Criticality model (2)

- r⁰ can vary in [0,1]
- Behavior functions (BV) defines the capture speed according to r⁰
- r⁰ < 0.5
  - Concave shape BV
- r⁰ > 0.5
  - Convex shape BV
- We propose to use Bezier curves to model BV functions



# Behavior function

$$B(t) = (1-t)^2 * P_0 + 2t(1-t) * P_1 + t^2 * P_2$$

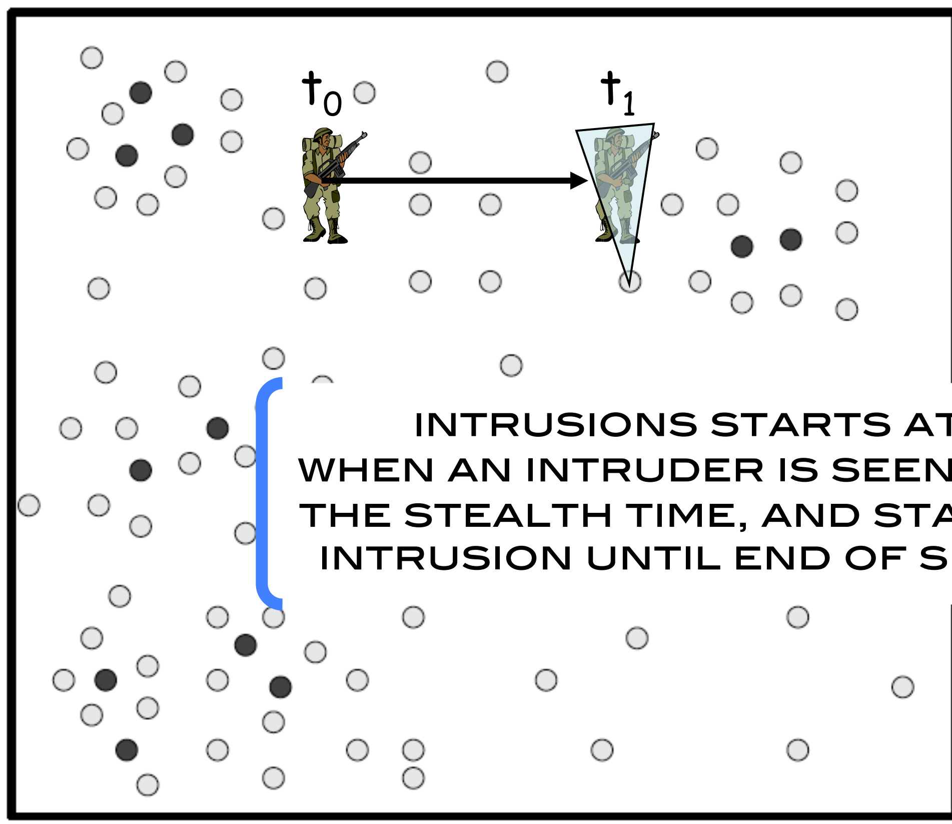


# Risk-based scheduling

- Static risk-based scheduling
  - r°=Cte in [0,1]
- Dynamic risk-based scheduling
  - Starts with a low value for r° (0.1)
  - On intrusion, alert neighborhood and increases r° to a $r_{max}$ value (0.9)
  - Stays at $r_{max}$ for $T_a$ seconds before going back to r°
- Dynamic with reinforcement
  - Same as dynamic but several alerts are needed to get to r°= $r_{max}$
  - Going back to r° is done in one step

# MEAN STEALTH TIME

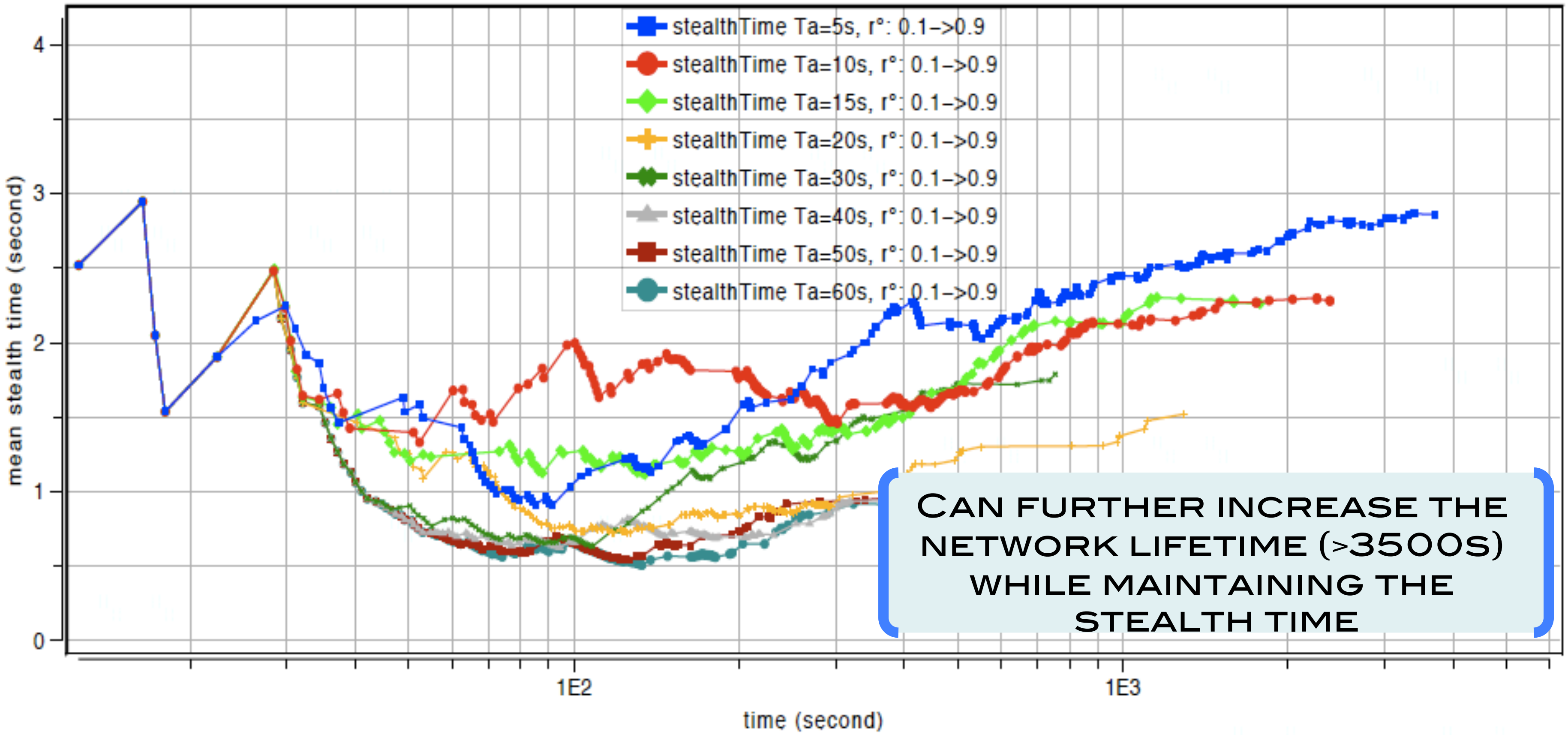
$T_1 - T_0$ IS THE INTRUDER'S STEALTH TIME
VELOCITY IS SET TO 5M/S




INTRUSIONS STARTS AT T=10S
WHEN AN INTRUDER IS SEEN, COMPUTE THE STEALTH TIME, AND STARTS A NEW INTRUSION UNTIL END OF SIMULATION

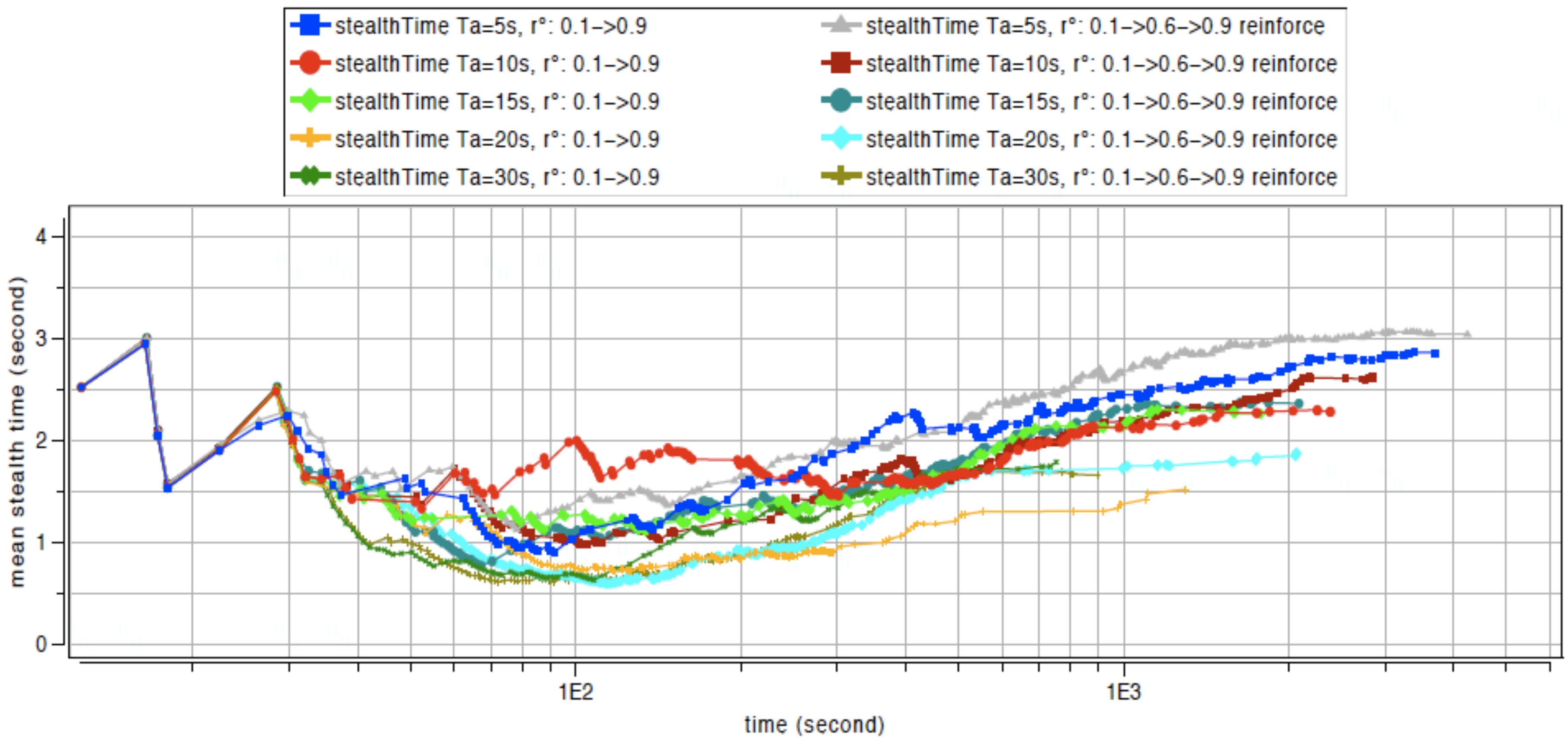
# DYNAMIC SCHEDULING

- $r° = 0.1$, $r_{MAX} = 0.9$, $T_A = 5, 10, 15, 20..60s$



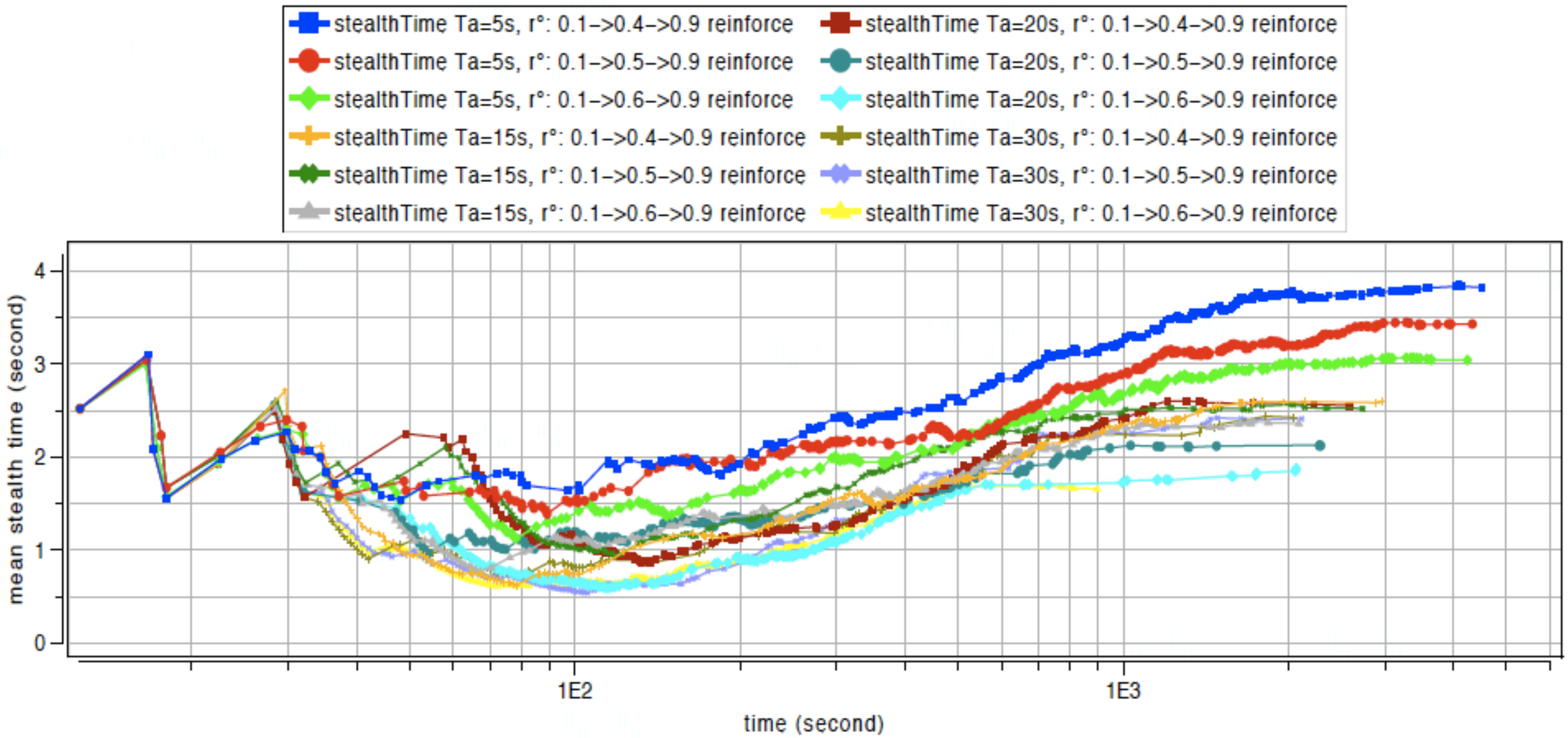
# Dynamic with reinforcement (1)

- ❑ $R° = 0.1 \rightarrow I_R = 0.6 \rightarrow R_{MAX} = 0.9$
- ❑ 2 alert msg to have $I_R = I_R + 0.1$

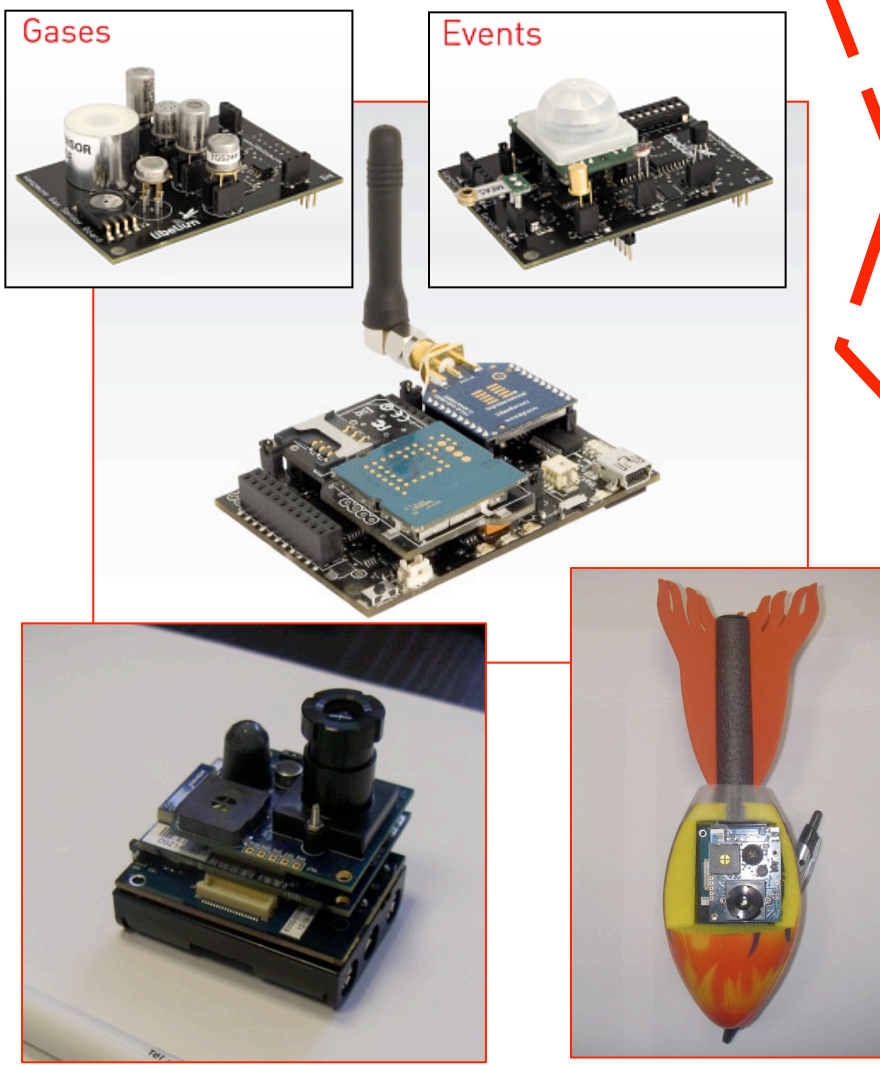


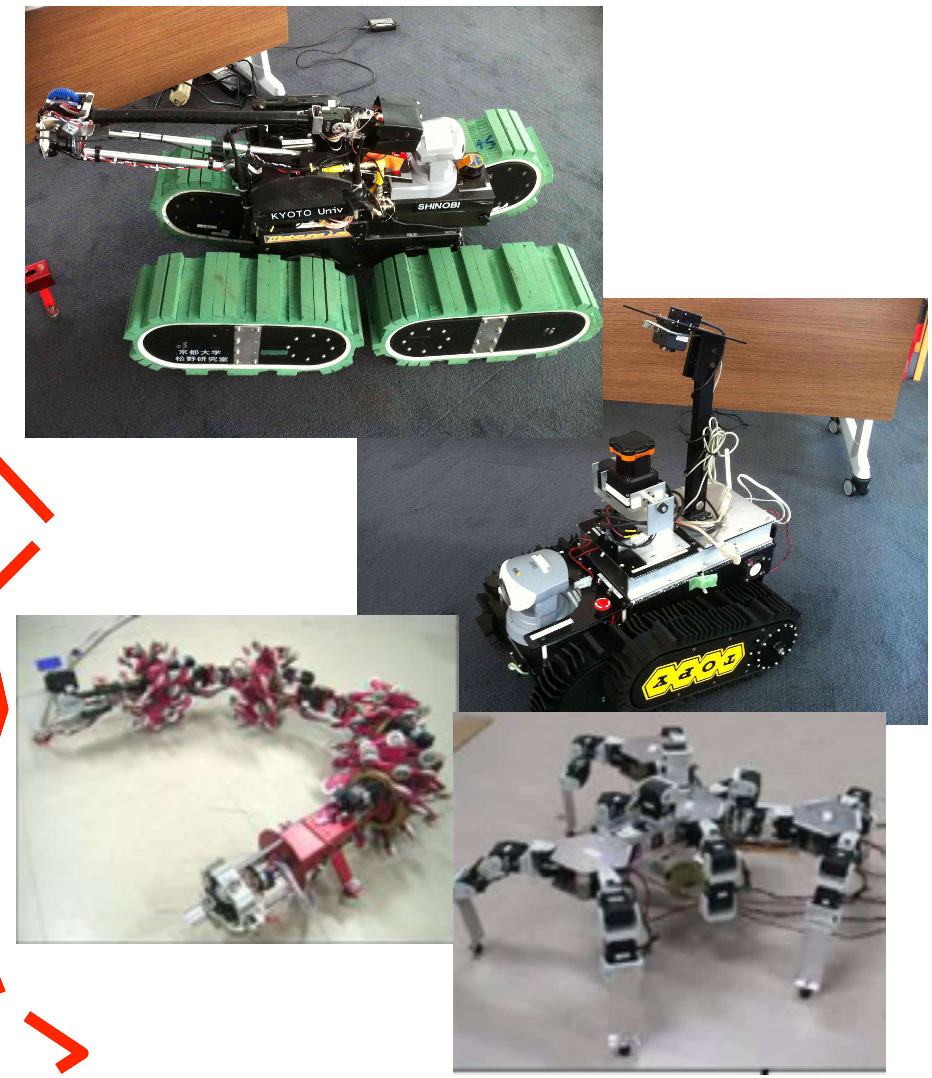
# Dynamic with reinforcement (2)

- $r° = 0.1 \rightarrow I_R = 0.4/0.5/0.6 \rightarrow r_{MAX} = 0.9$
- 2 alert msg to have $I_R = I_R + 0.1$



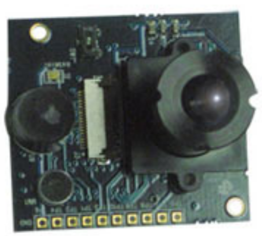
# Challenging cooperation implies differences!



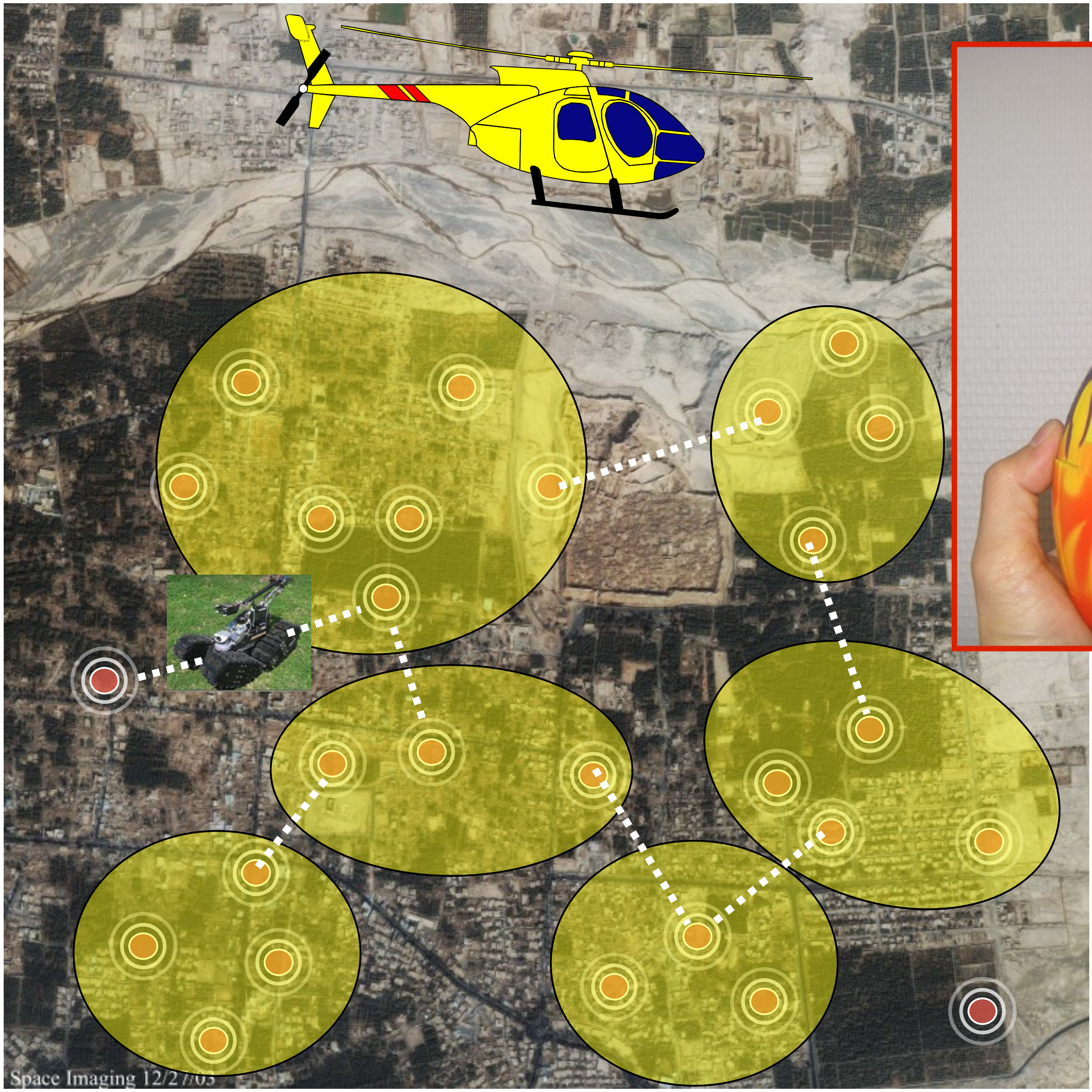



# Robot's mobility to preserve connectivity

Imote2



Multimedia board




# Sensor & Robots Search & Rescue

- Rescue could be operated in several phases (1)

Deploy in mass a WSN to get a first snapshot of the situation: images, radiation level, targets,…

# Sensor & Robots Search & Rescue

- Rescue could be operated in several phases (2)

Based on collected data, optimize deployment/ selection of autonomous robots

# Sensor & Robots
# Search & Rescue

- Rescue could be operated in several phases (3)

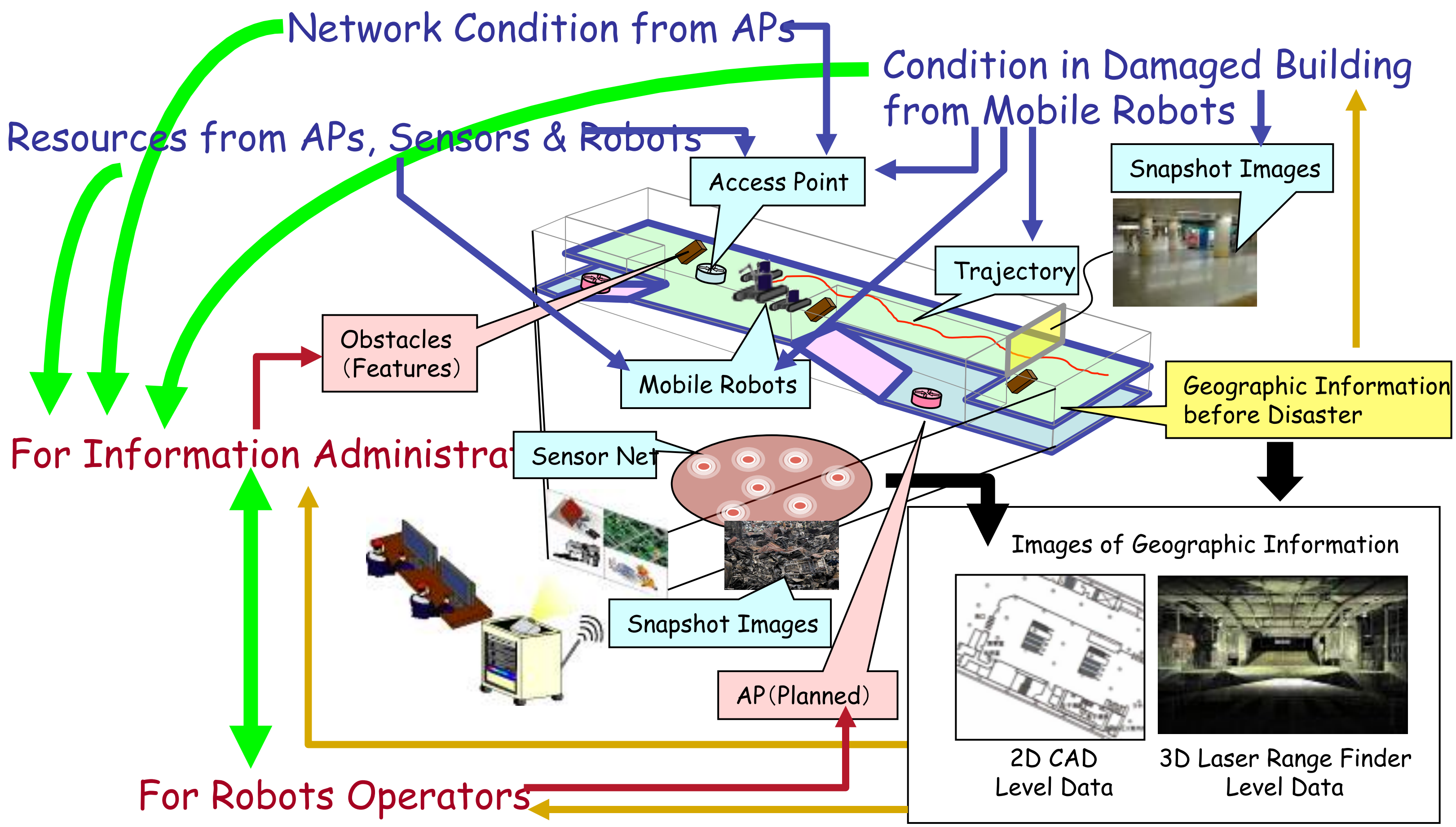
Robots could serve as relay or install communication gateways to maintain WSN connectivity and increase data storage capability

# Sensor & Robots Search & Rescue

- Rescue could be operated in several phases (4)

Sensor & Robots will contineously collaborate during the rescue process: localization, path optimization, remote sensing,…

# Disaster Management Information Systems

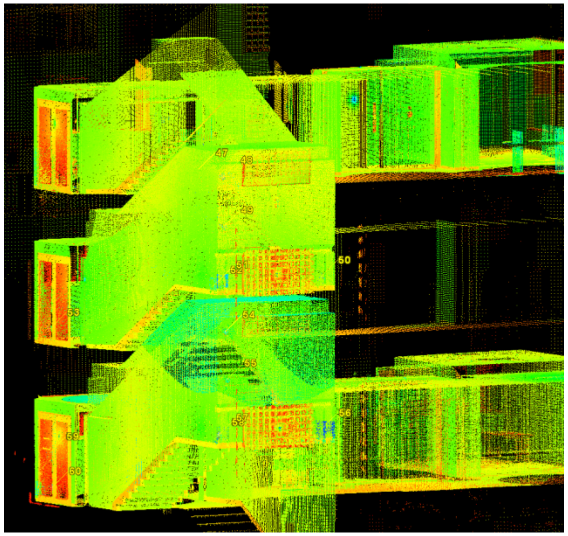



From « Development of Temporal GIS Server Unit for Grouped Rescue Robots System", Michinori HATAYAMA(DPRI, Kyoto Univ.), Hisashi Mizumoto (Kyoto University), Fumitoshi Matsuno (Kyoto University). Slides presented at ROSIN 10. Modified by C. Pham with sensor nets.

# Making Base GIS Data

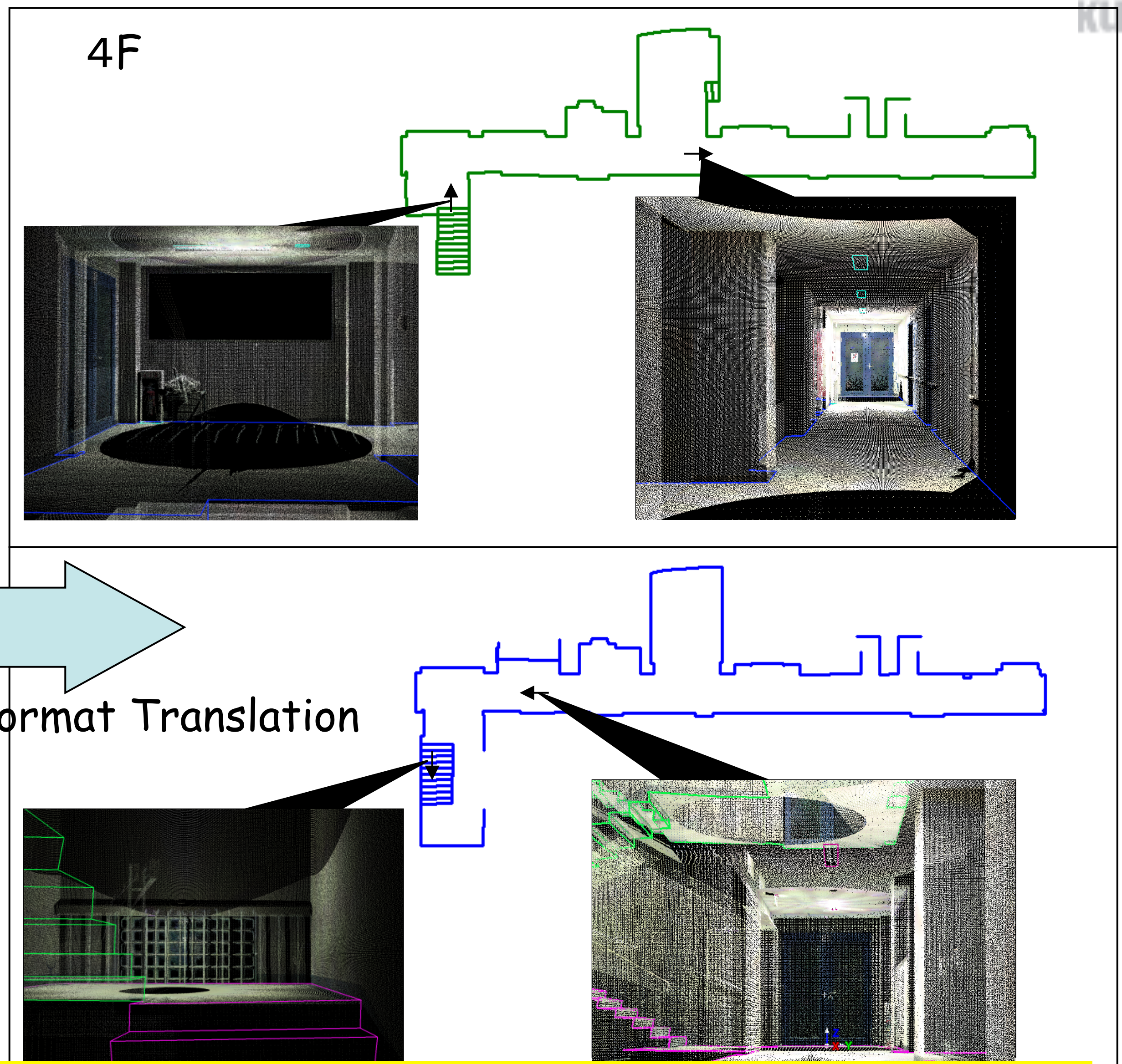
3D Laser Range Finder

accuracy：mm



Points to Polygons

Format Translation

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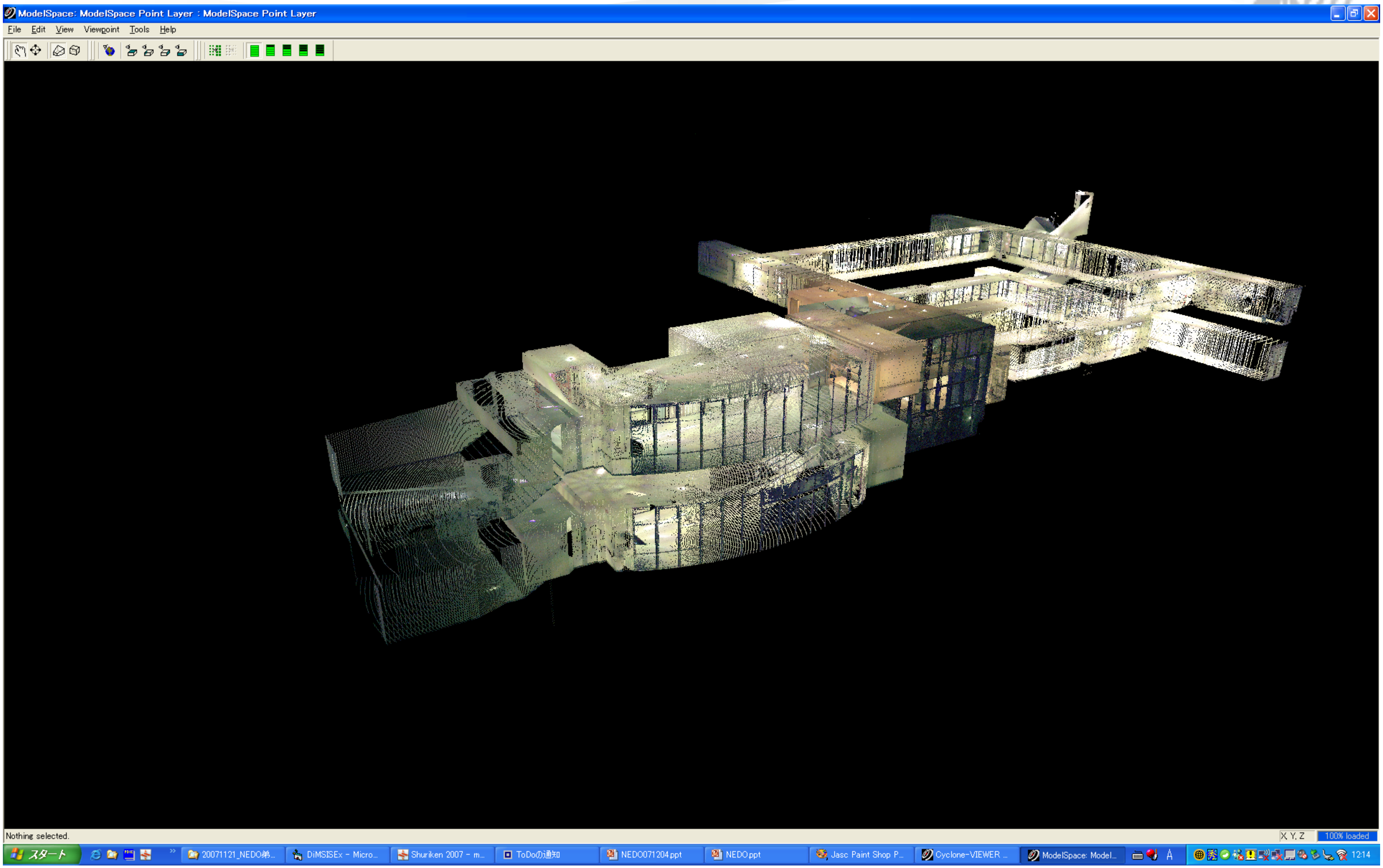


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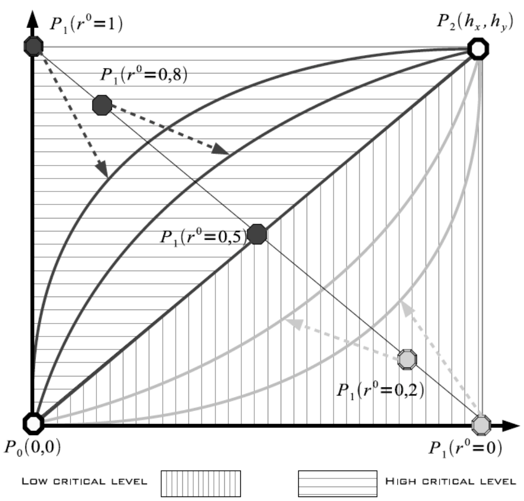
# [ Sensors & Robots Propose new interaction schemes ]

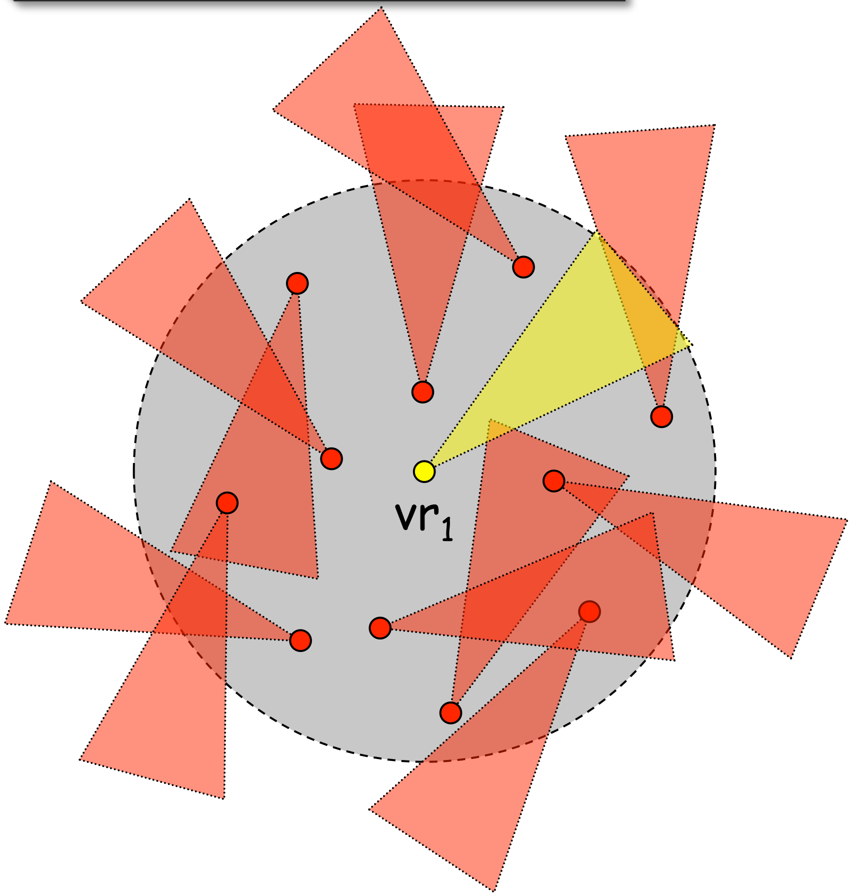
- Use the criticality model to control both sensors and robots
- Prototyping on real hardware, collaboration with U. Kyoto, Japan

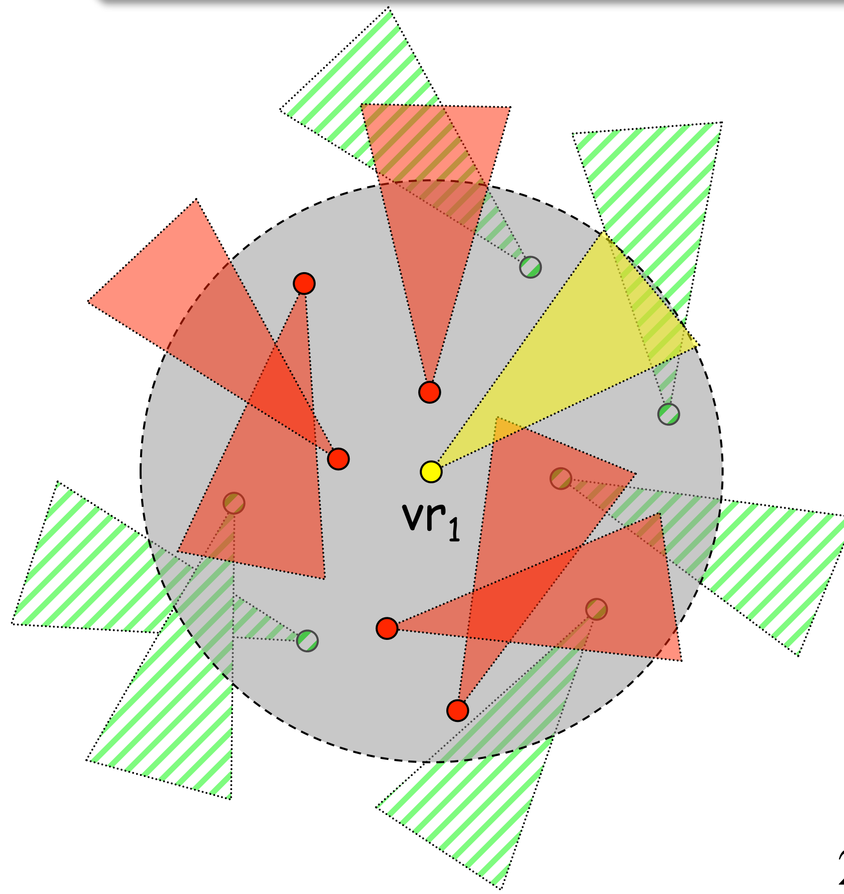



# Cooperation with cameras on mobile robots

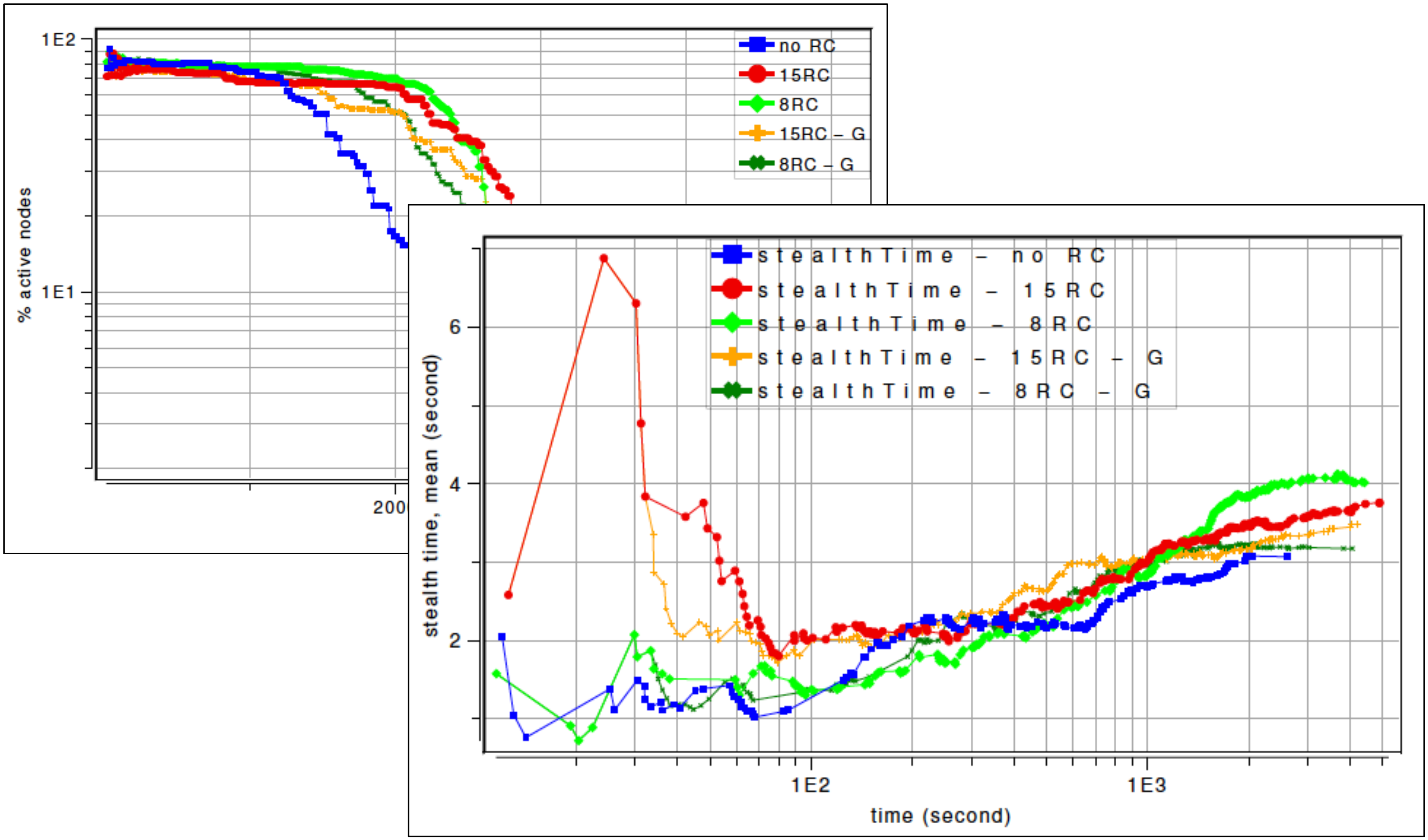
Fixed image sensors near a mobile camera can decrease their criticality level

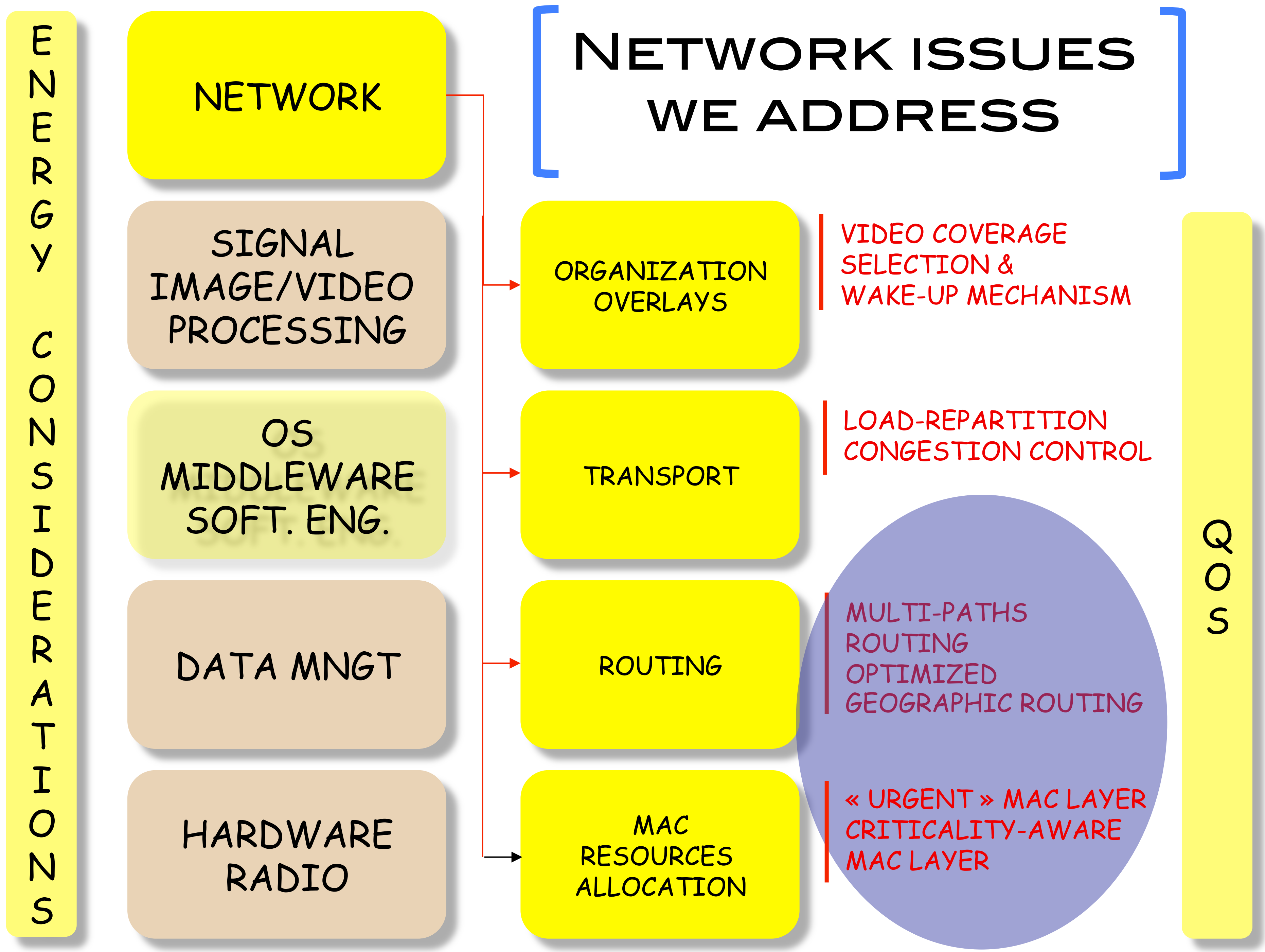
**ONLY** fixed image sensors whose FoV's center is covered by a mobile camera **CAN** decrease their criticality level



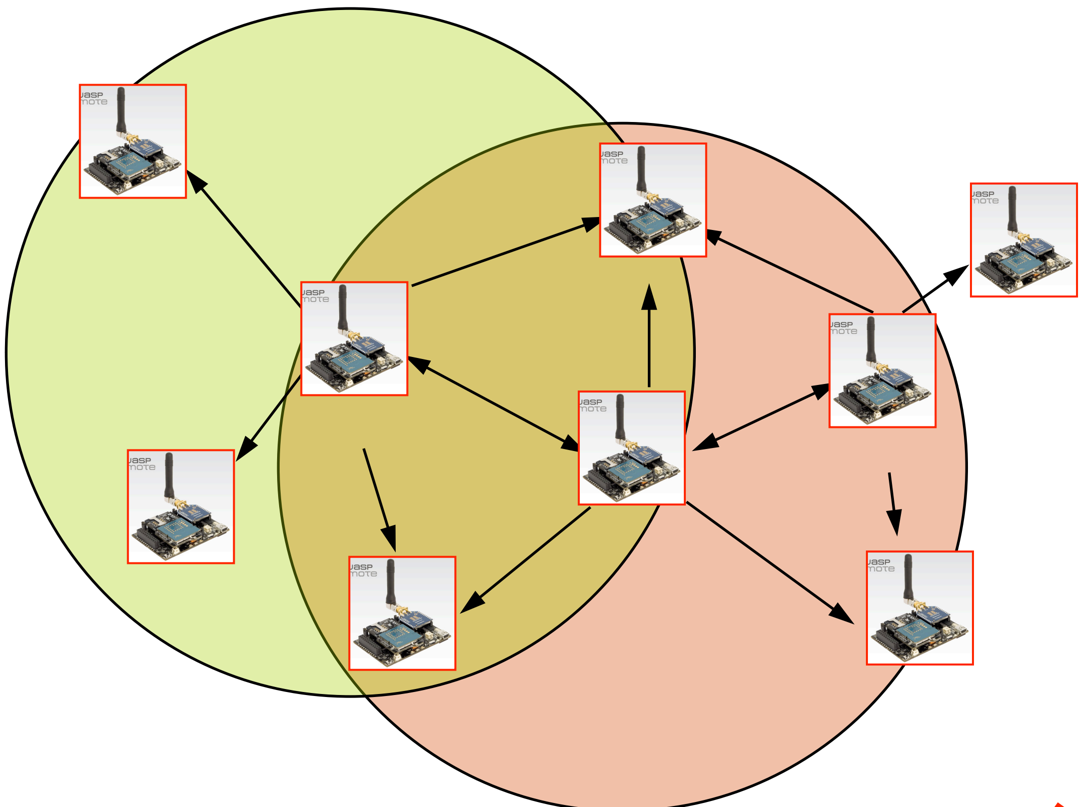



# IMPACT ON LIFETIME & STEALTH TIME




ENERGY CONSIDERATIONS
NETWORK
SIGNAL IMAGE/VIDEO PROCESSING
OS MIDDLEWARE SOFT. ENG.
DATA MNGT
HARDWARE RADIO
NETWORK ISSUES WE ADDRESS
ORGANIZATION OVERLAYS
VIDEO COVERAGE SELECTION & WAKE-UP MECHANISM
TRANSPORT
LOAD-REPARTITION CONGESTION CONTROL
ROUTING
MULTI-PATHS ROUTING OPTIMIZED GEOGRAPHIC ROUTING
MAC RESOURCES ALLOCATION
« URGENT » MAC LAYER CRITICALITY-AWARE MAC LAYER
QOS

# Wireless Medium is a Shared Medium



Collisions when multiple transmissions

Hidden terminal problem

WiFi transmission power is too energy-consuming for WSN!

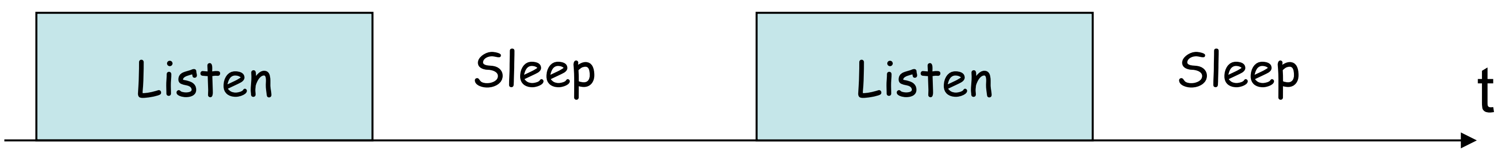
Huge cost of passive listening!

WSN can be idle for a long period!

TDMA is usually not used because of waste of resource

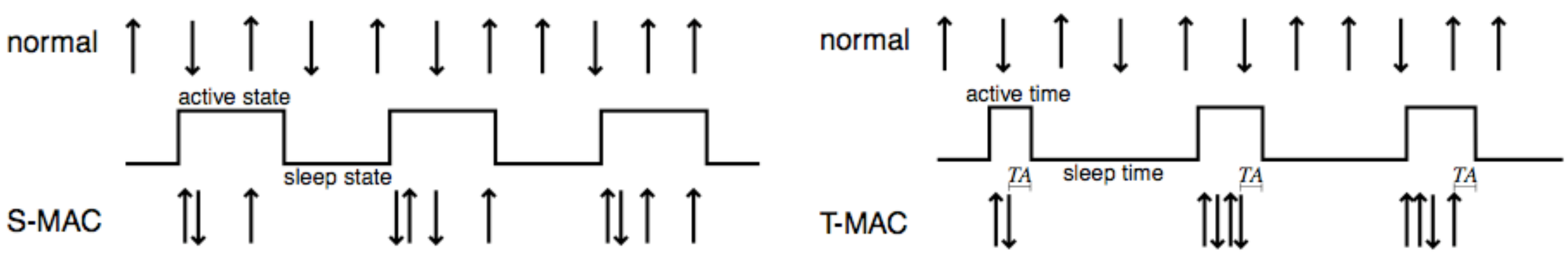
# S-MAC - Sensor MAC

- Nodes periodically sleep
- Trades energy efficiency for lower throughput and higher latency
- Sleep during other nodes transmissions



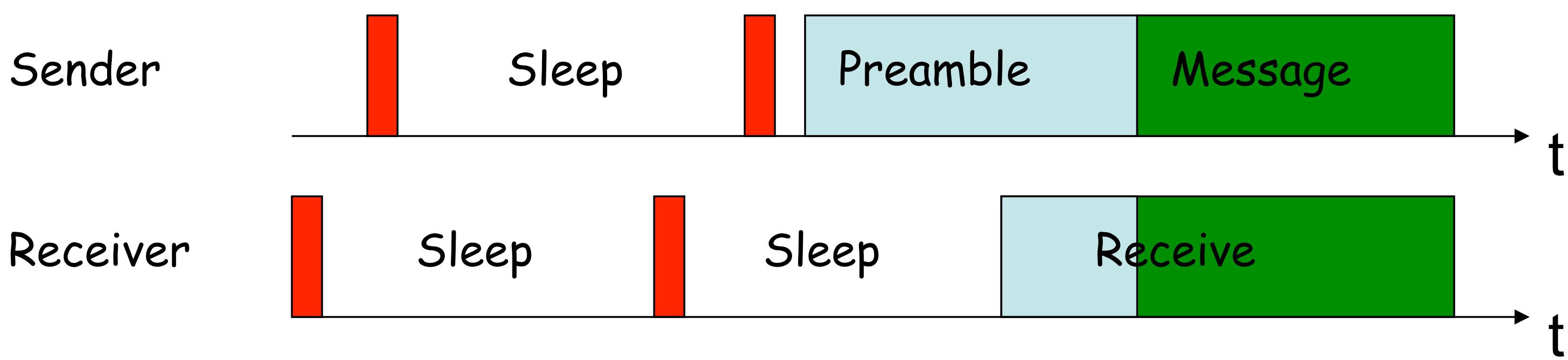
# T-MAC - Timeout MAC

- Transmit all messages in bursts of variable length and sleep between bursts
- RTS / CTS / ACK Scheme
- Synchronization similar to S-MAC



# B-MAC

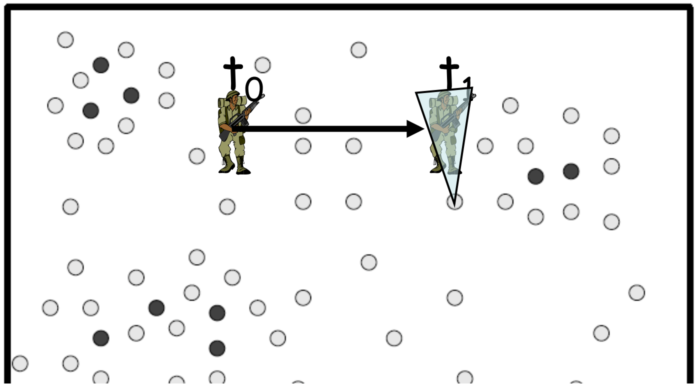
- Low Power Listening (LPL) using preamble sampling
- Hidden terminal and multi-packet mechanisms not provided, should be implemented, if needed, by higher layers



# Challenges for MAC protocols in WSN

- Energy efficiency
- Low latencies
- Fairness

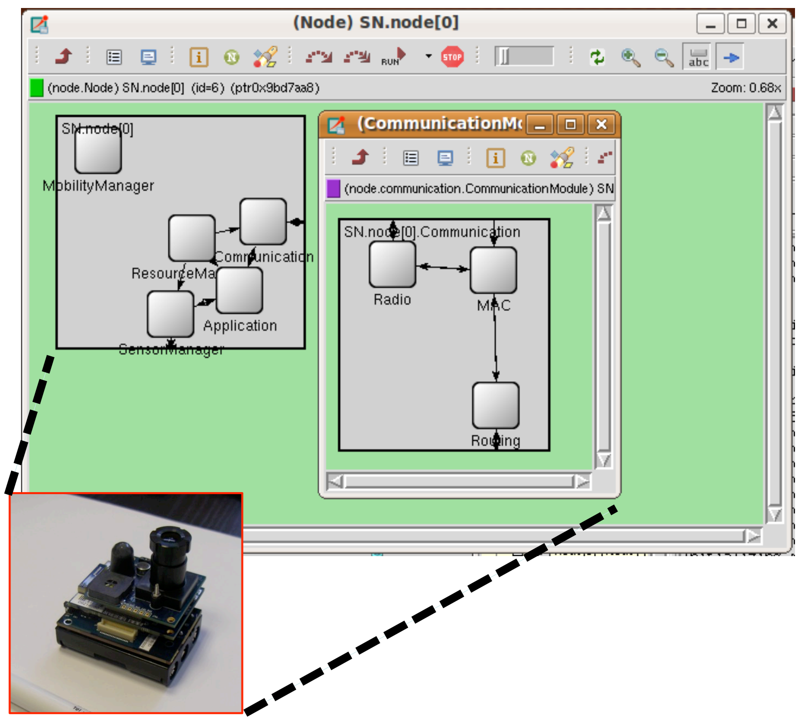
**A CHALLENGE FOR MISSION-CRITICAL APPLICATION**

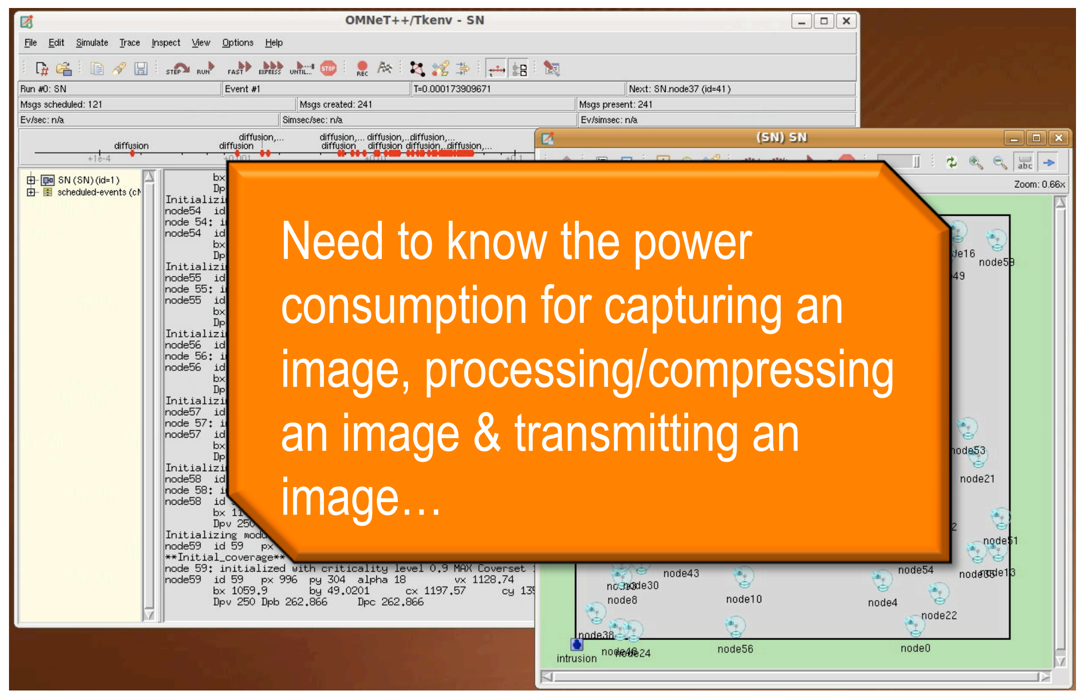


# Simulation Tools

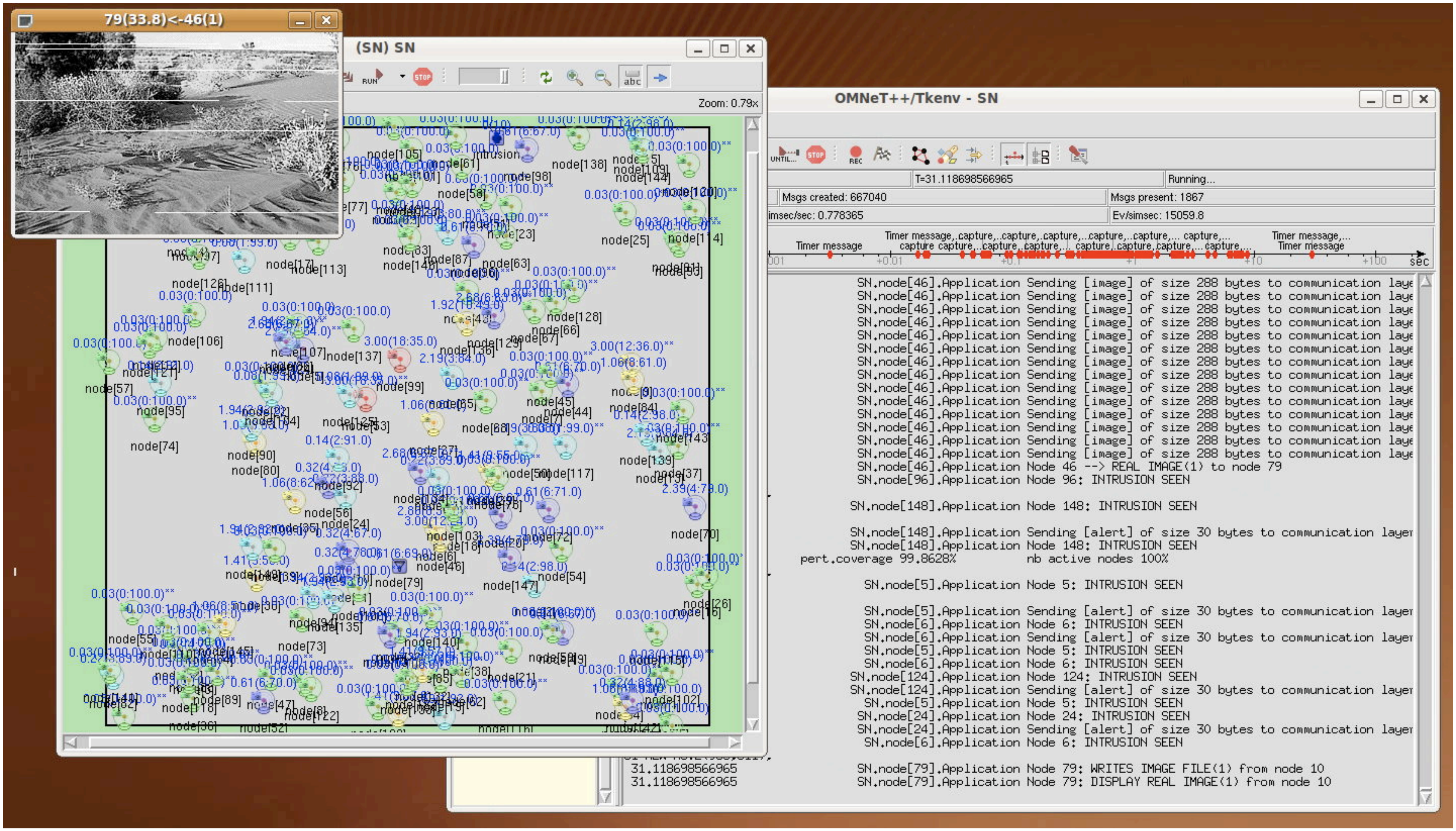
# Image sensor simulation model under OMNET++

- Communication layers are very important for WSN
- Use specific simulator



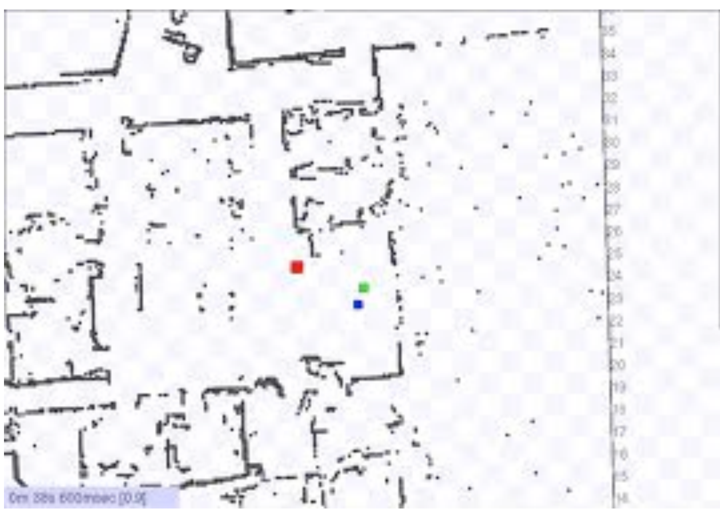



# Study the impact of communication layer on surveillance quality



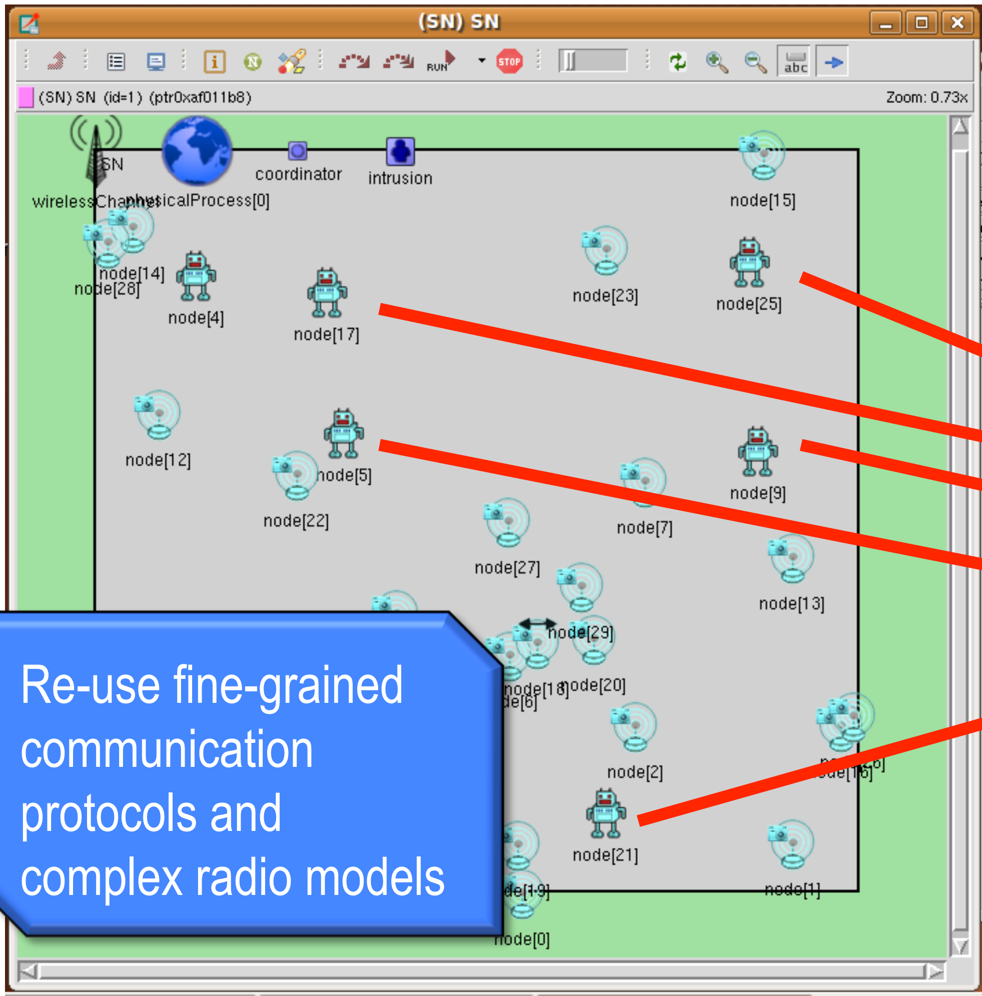
# Robot simulators

- Mobility, exploration, navigation, tracking, control and design are very important for robots
- Use specific robot simulators

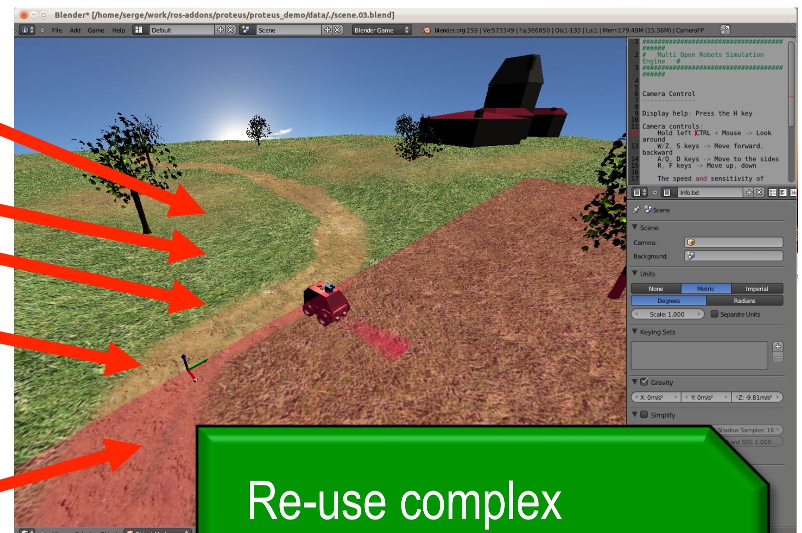


# SENSORS & ROBOTS ENABLE REALISTIC INTERACTION STUDIES

Sensor specific simulator for communication stack




Get robot's position from robot simulator



Re-use fine-grained communication protocols and complex radio models

Re-use complex hardware (laser scan, …) and control software (navigation stacks,…)