Visual Wireless Sensor Networks for mission-critical surveillance applications

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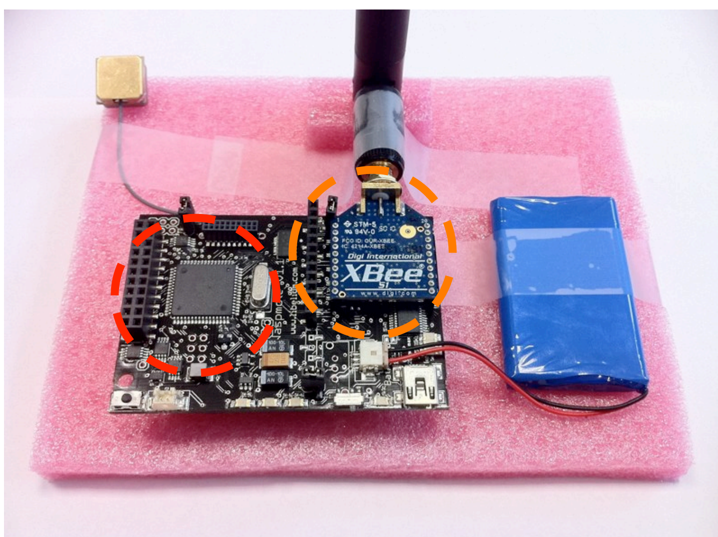
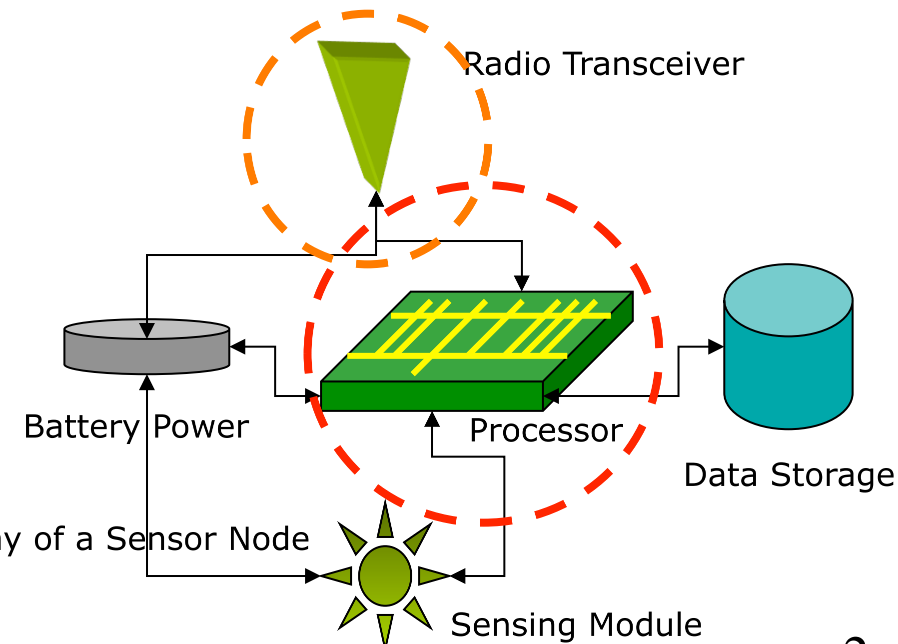
Wireless autonomous sensor

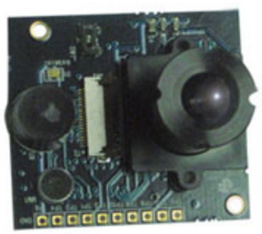
- In general: low cost, low power (the battery may not be replaceable), small size, prone to failure, possibly disposable
- Role: sensing, **data processing**, communication



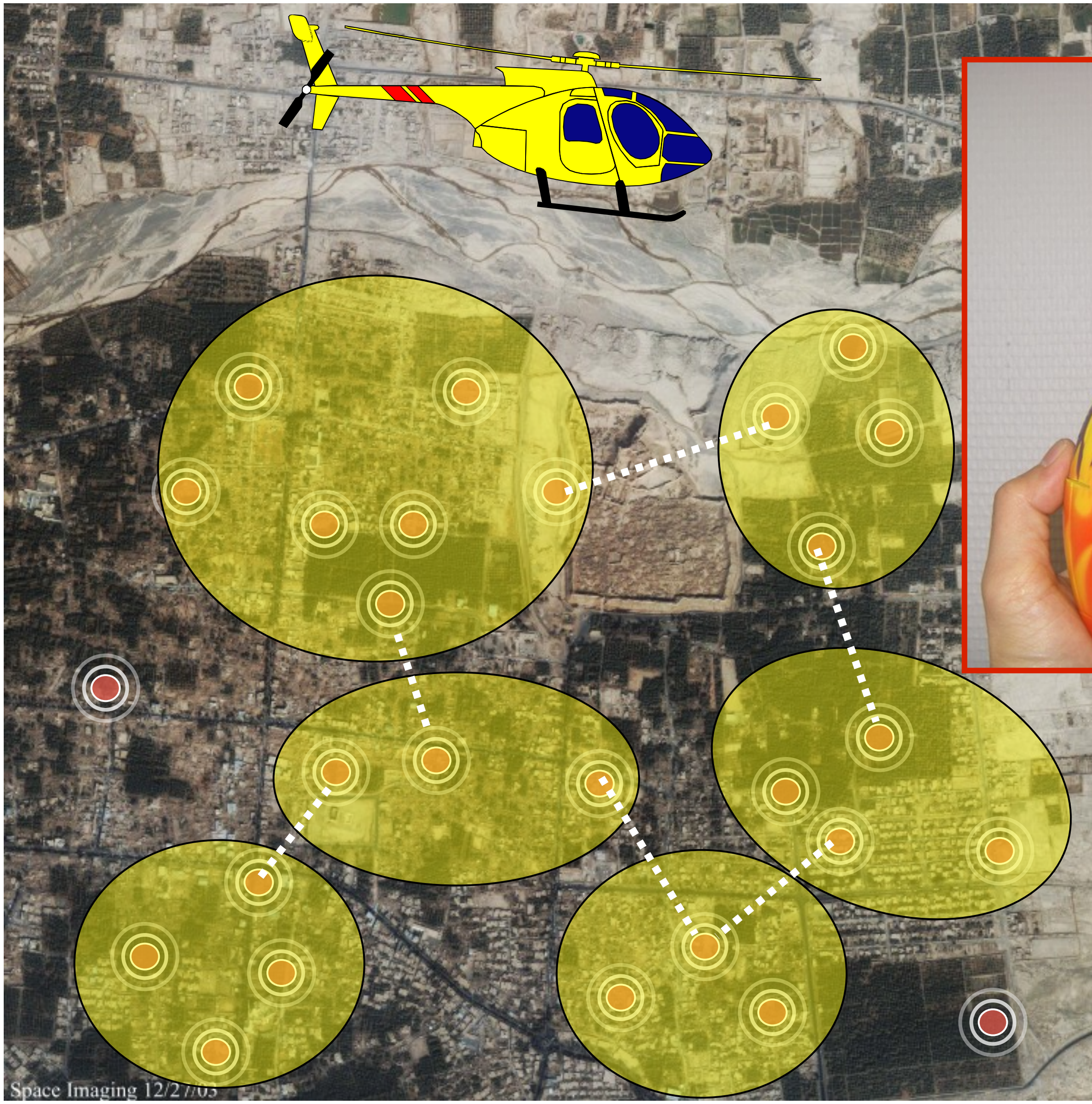


Search&Rescue, security

Imote2



Multimedia board



Don't miss important events!

Whole understanding of the scene is wrong!!!

What is captured

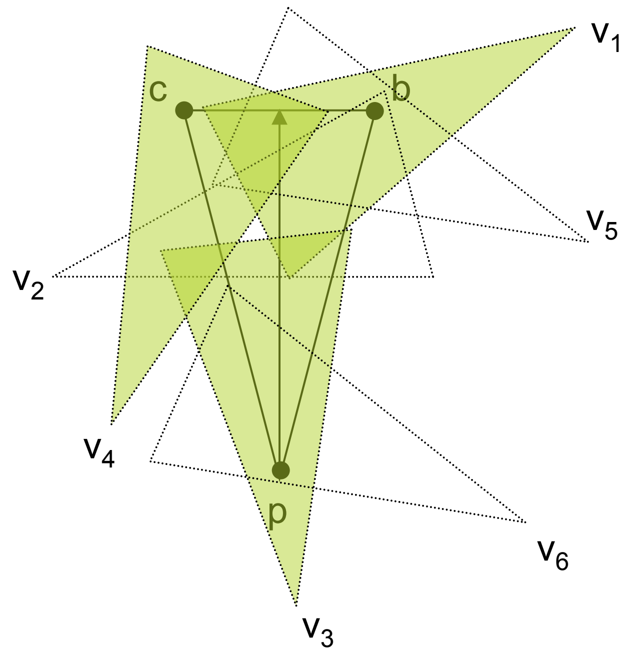
How to meet surveillance app's criticality

- 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

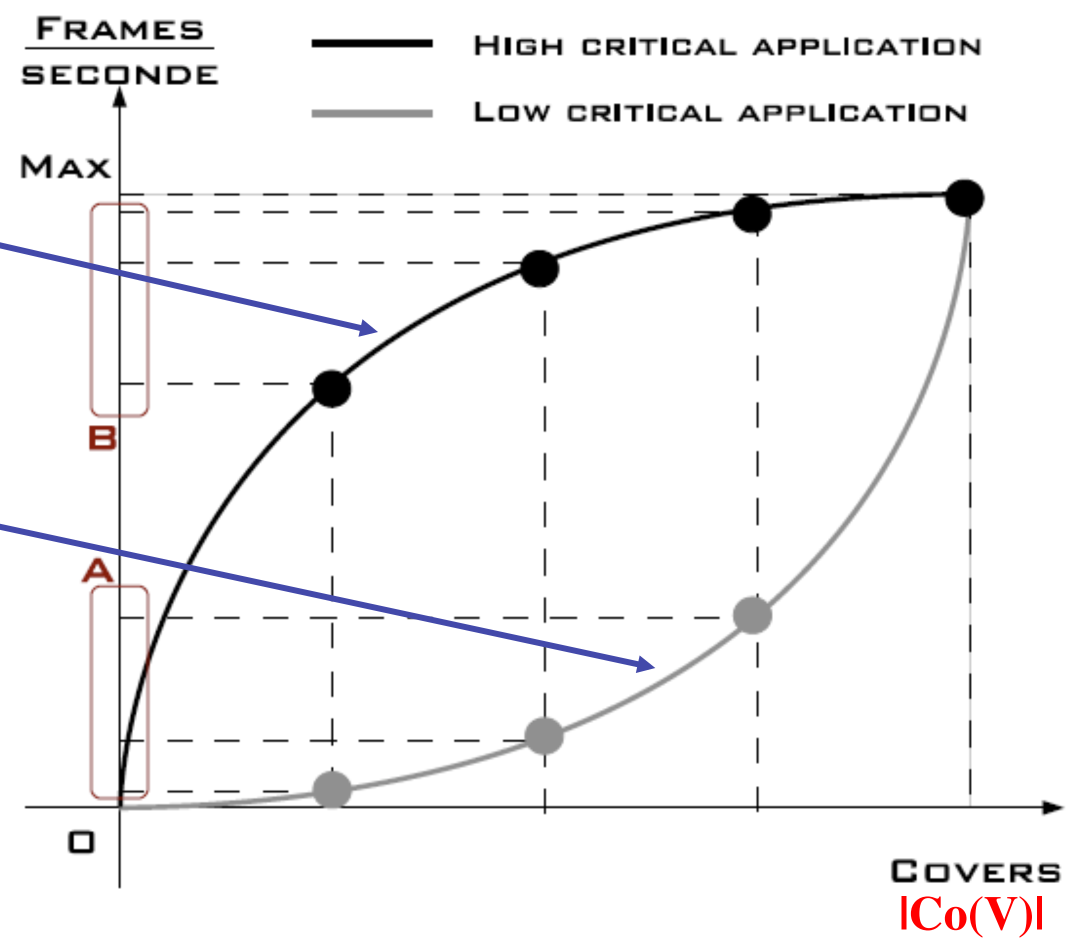
$\mathbf{Co(V)} = \{$
$\{V\},$
$\{V_1, V_3, V_4\},$
$\{V_2, V_3, V_4\},$
$\{V_3, V_4, V_5\},$
$\{V_1, V_4, V_6\},$
$\{V_2, V_4, V_6\},$
$\{V_4, V_5, V_6\}$
$\}$

$|\mathbf{Co(V)}| = 7$



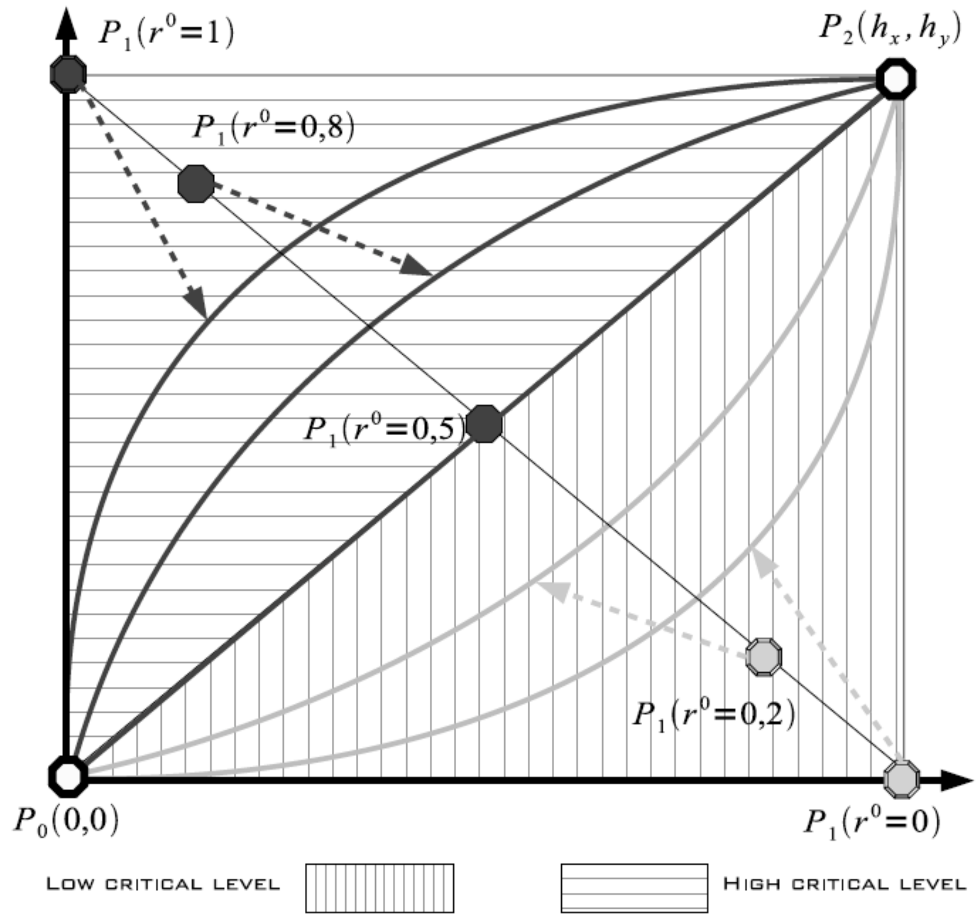
Criticality model (1)

- 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



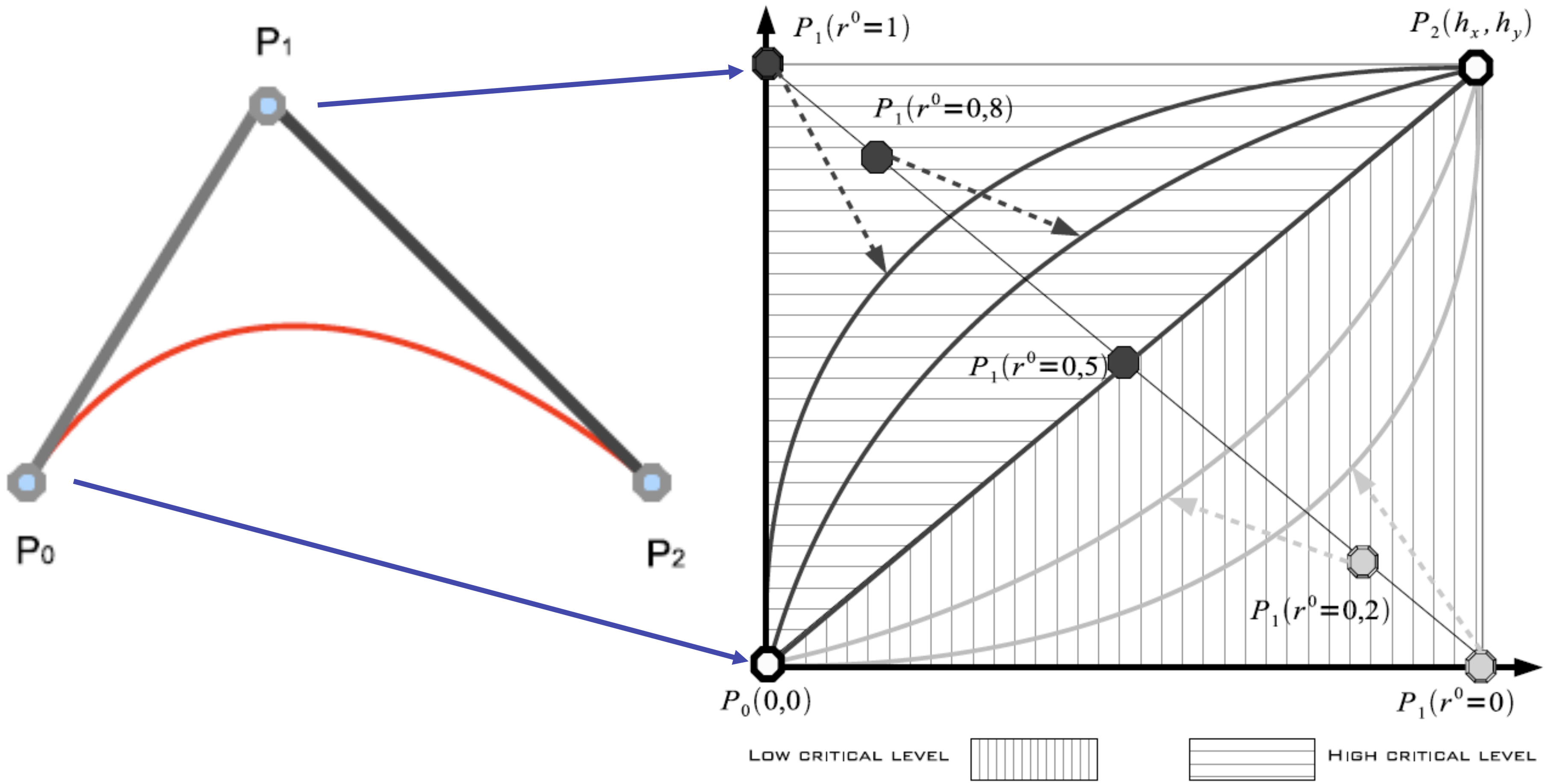
Criticality model (2)

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



BEHAVIOR FUNCTION

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

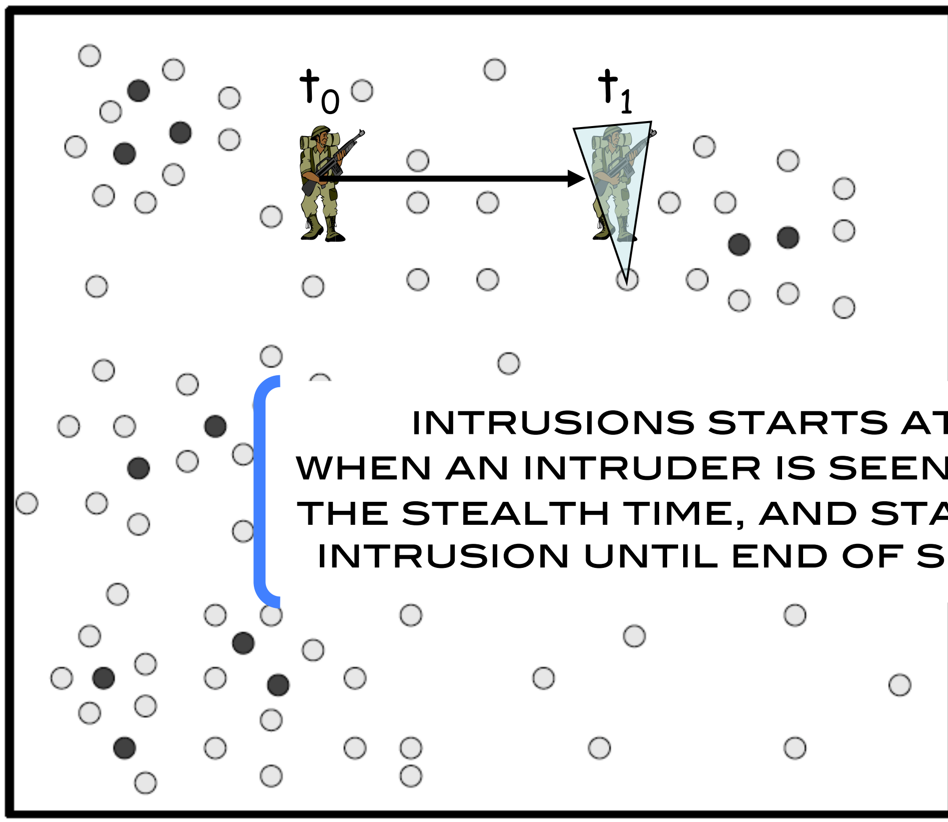


Risk-based scheduling

- 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

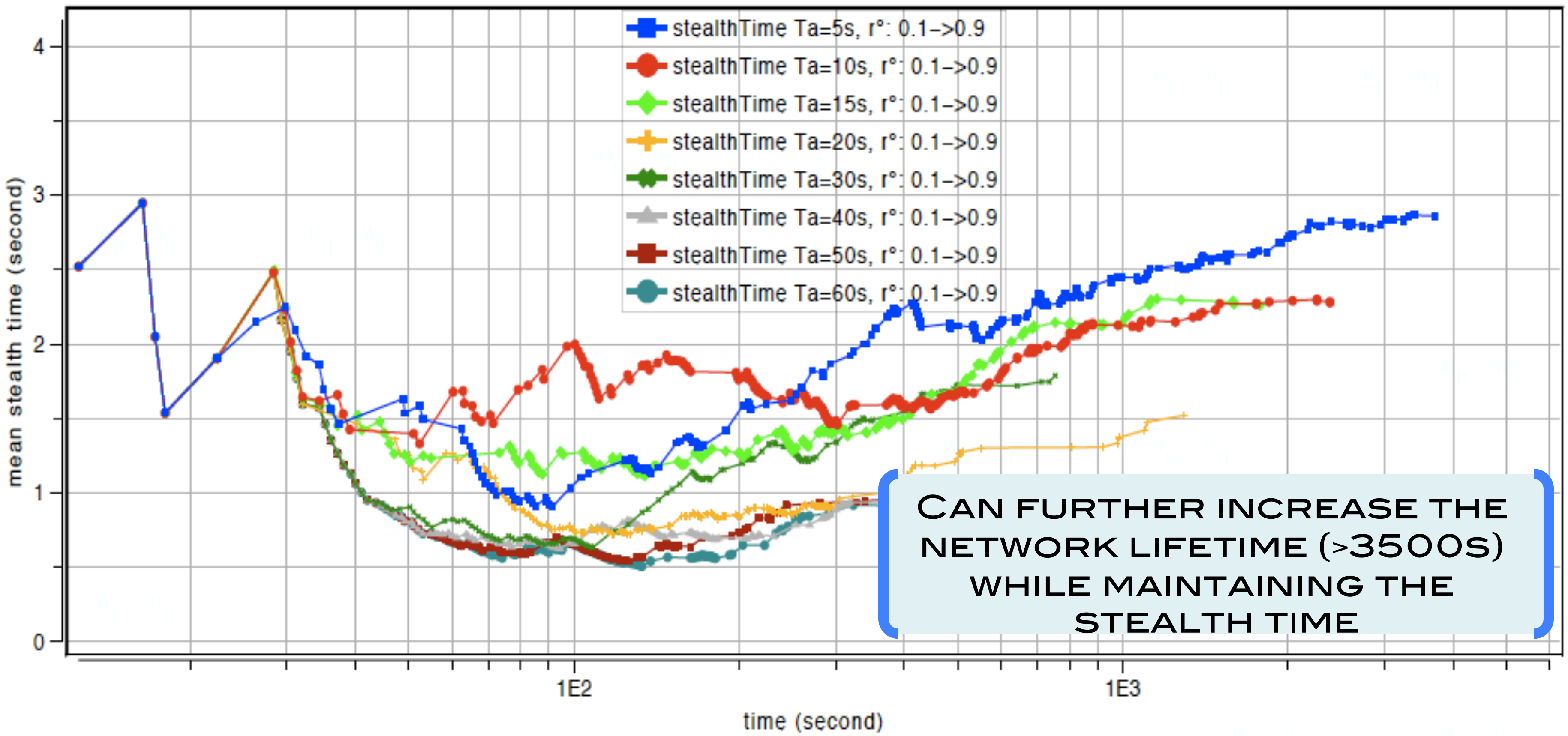
$T_1 - T_0$ IS THE INTRUDER'S
STEALTH TIME
VELOCITY IS SET TO 5M/S



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

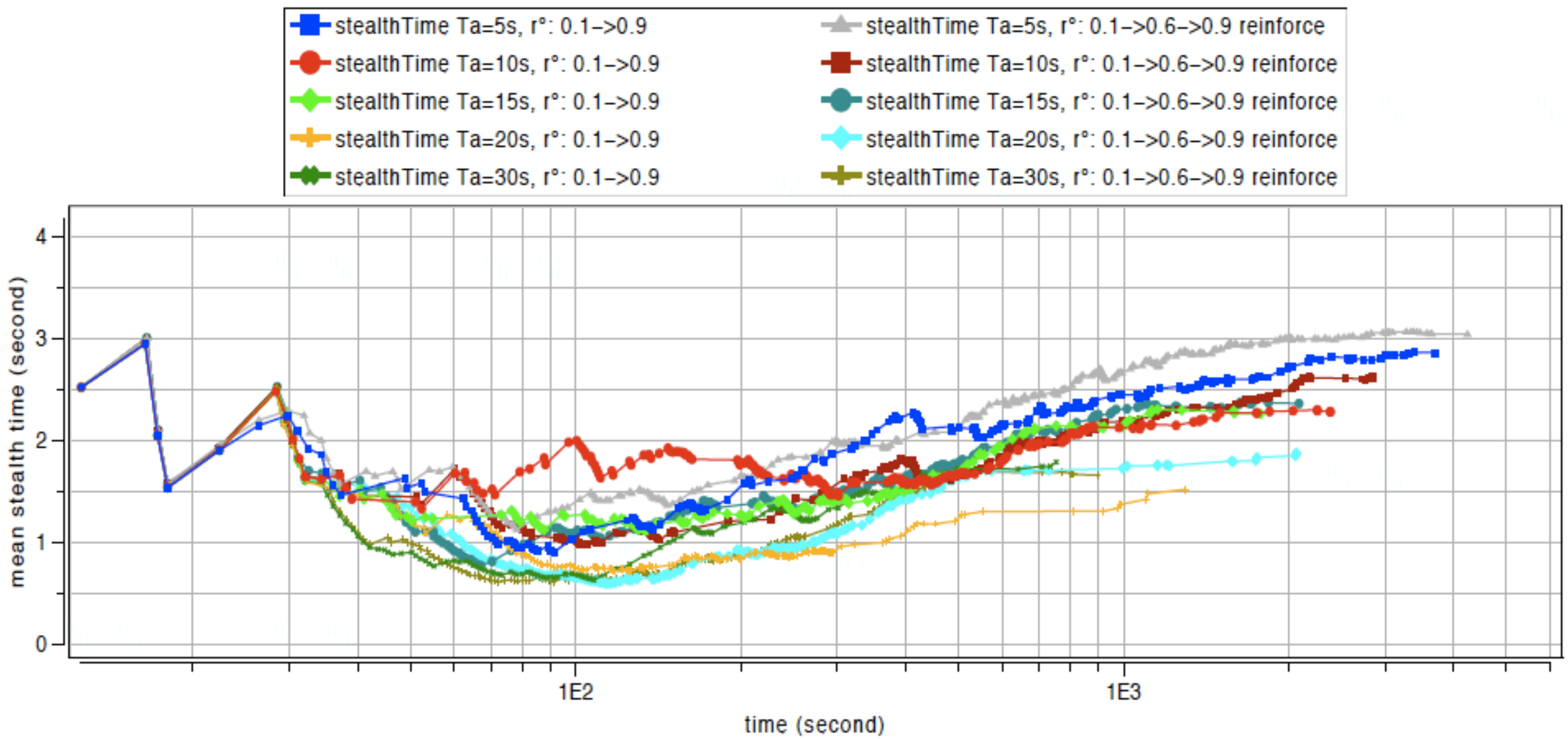
Dynamic scheduling

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



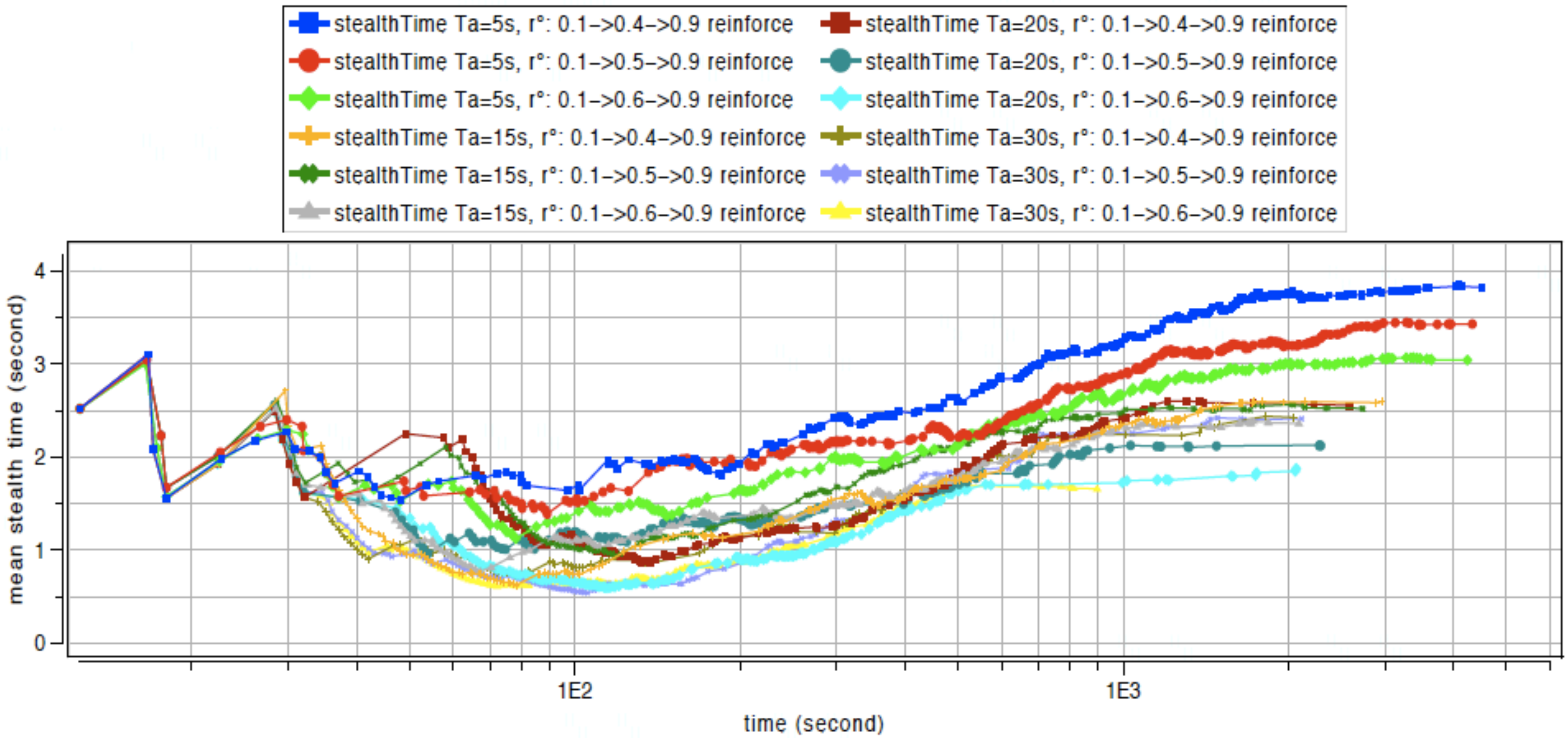
Dynamic with reinforcement (1)

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

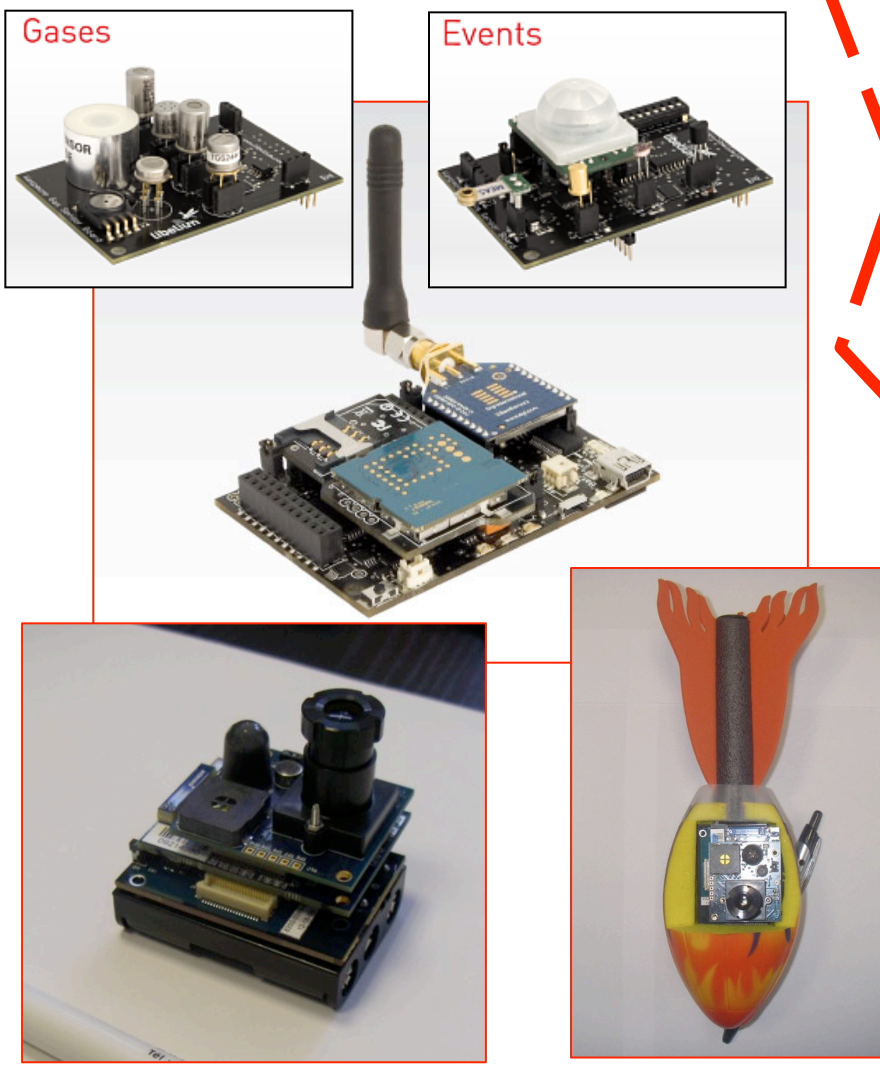


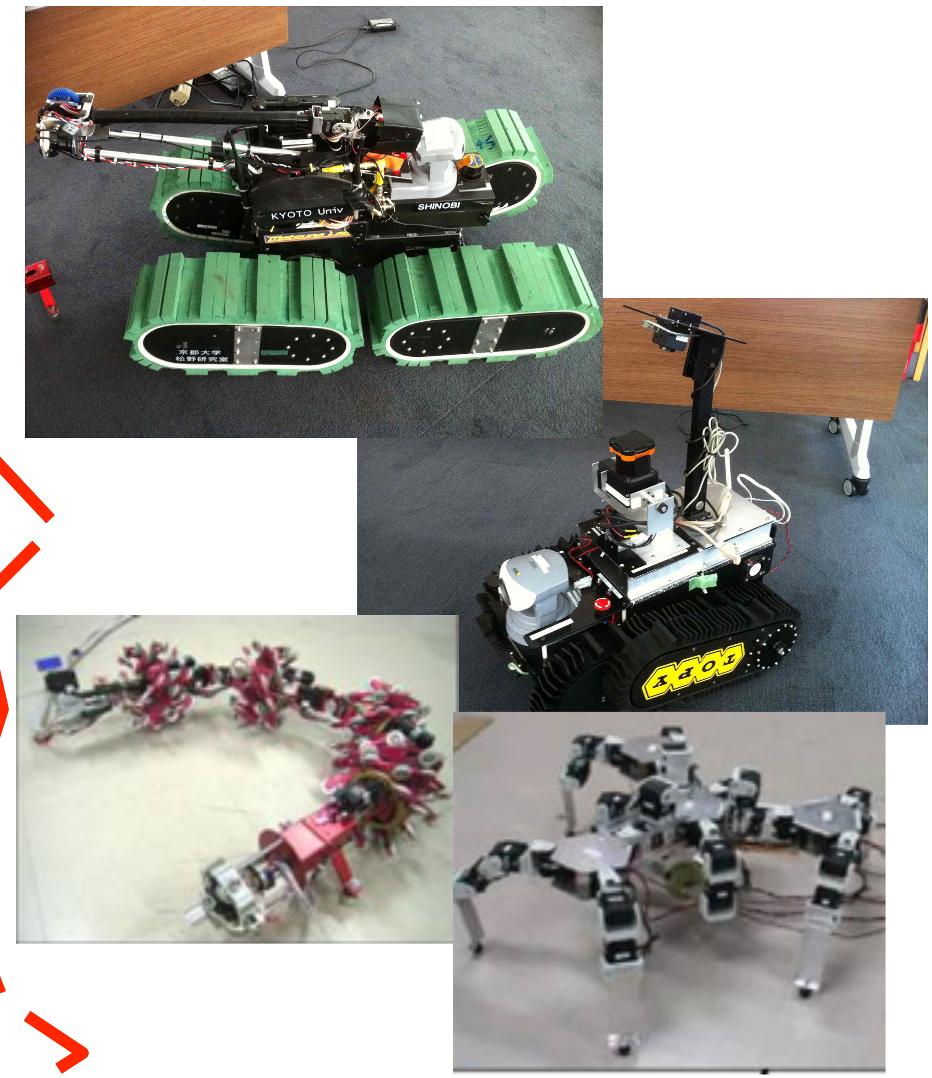
Dynamic with reinforcement (2)

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



Challenging cooperation implies differences!

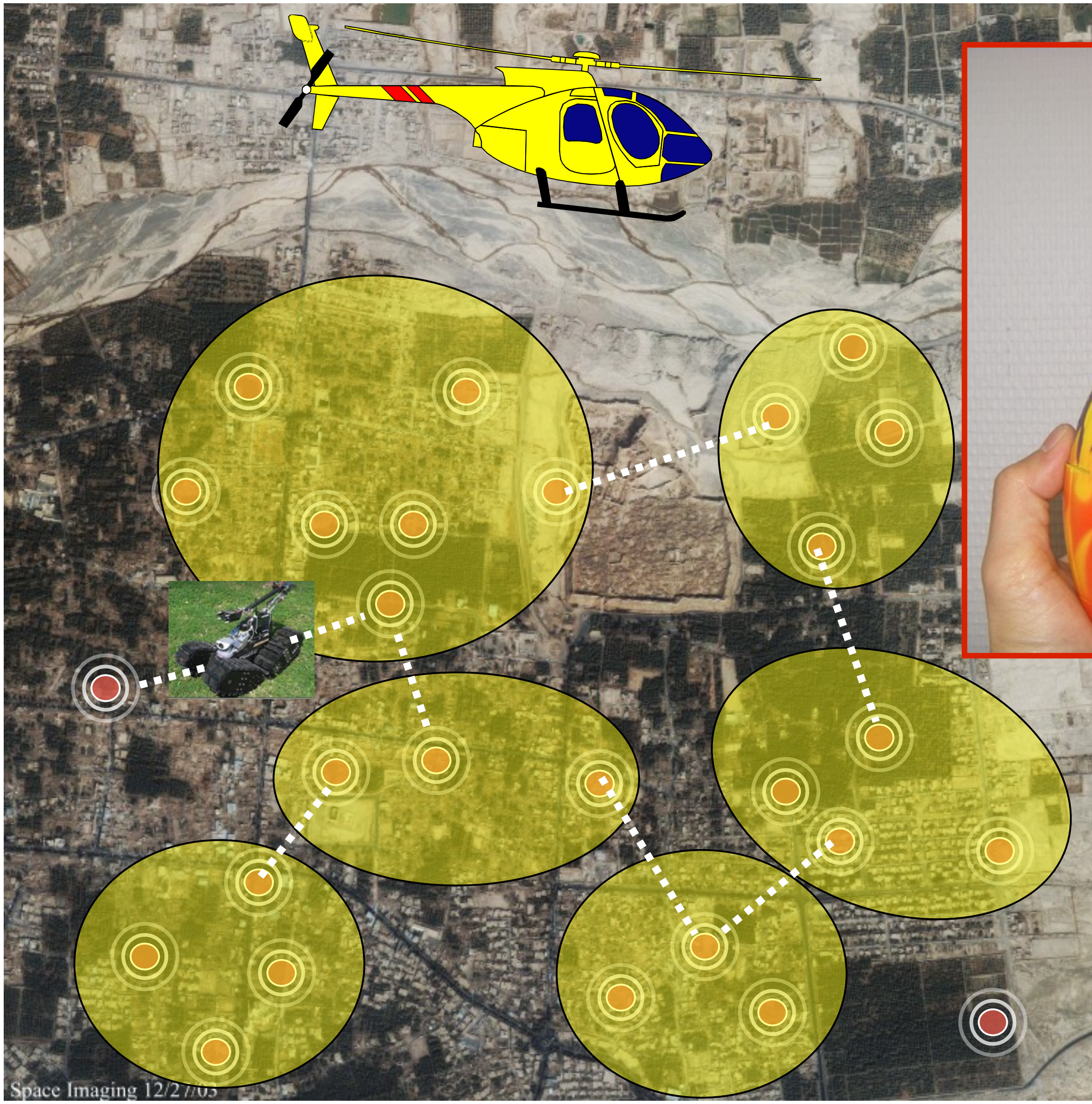




ROBOT'S MOBILITY TO PRESERVE CONNECTIVITY

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

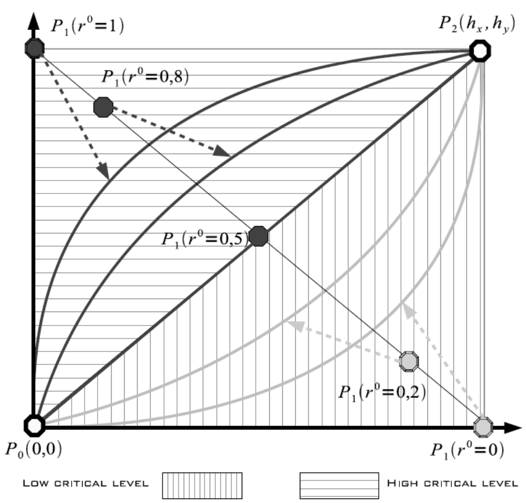
Sensor & Robots
Search & Rescue

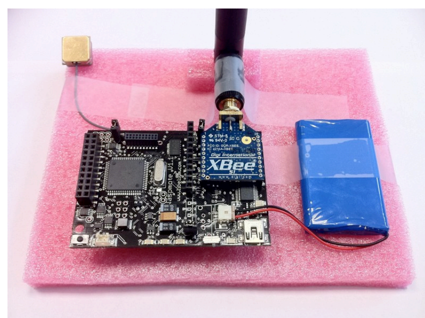
- Rescue could be operated in several phases (4)

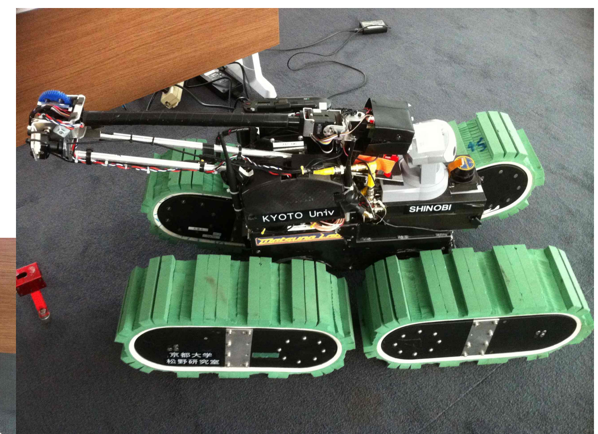
Sensor & Robots will contineously collaborate during the rescue process: localization, path optimization, remote sensing,…

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



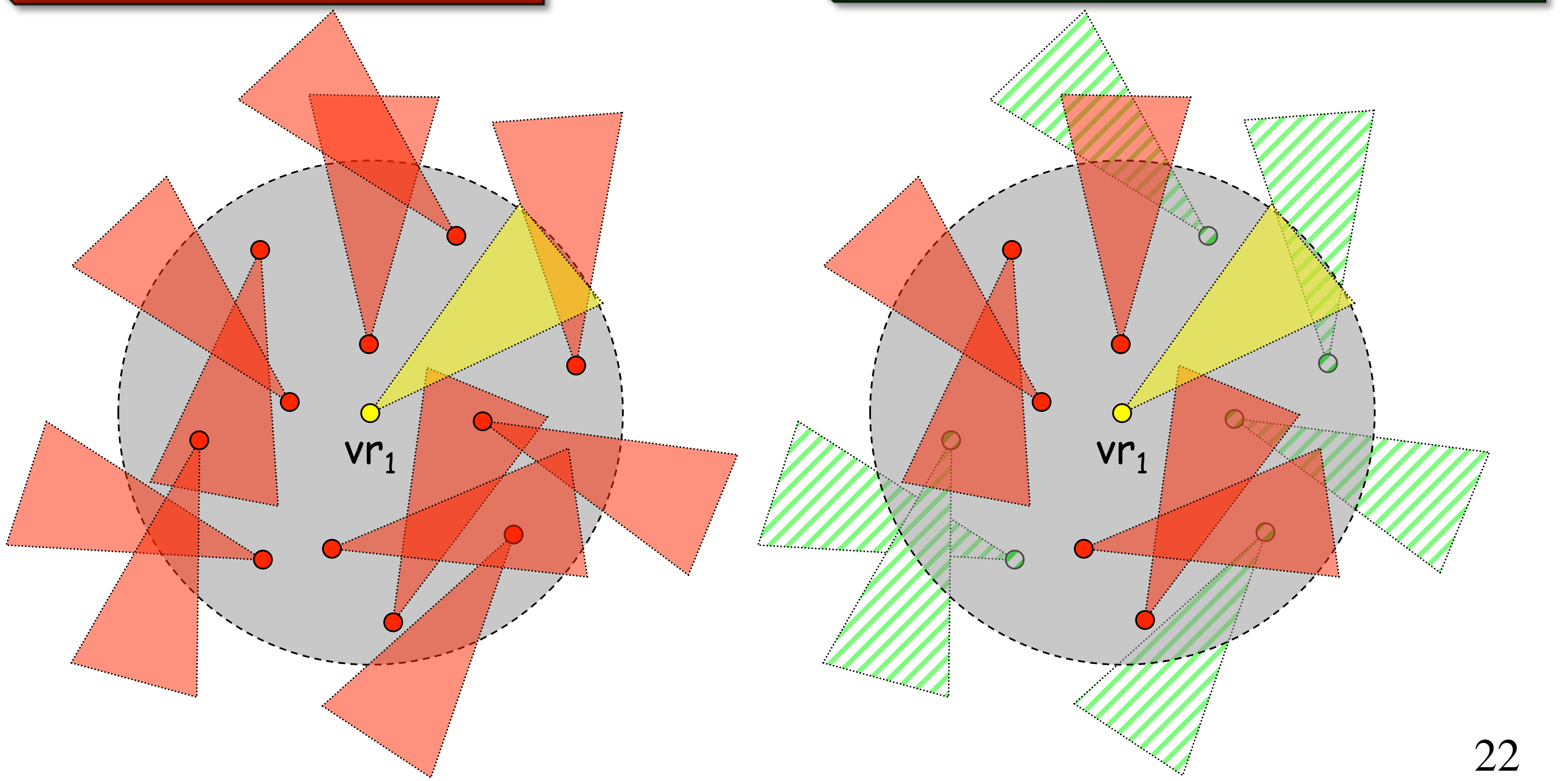




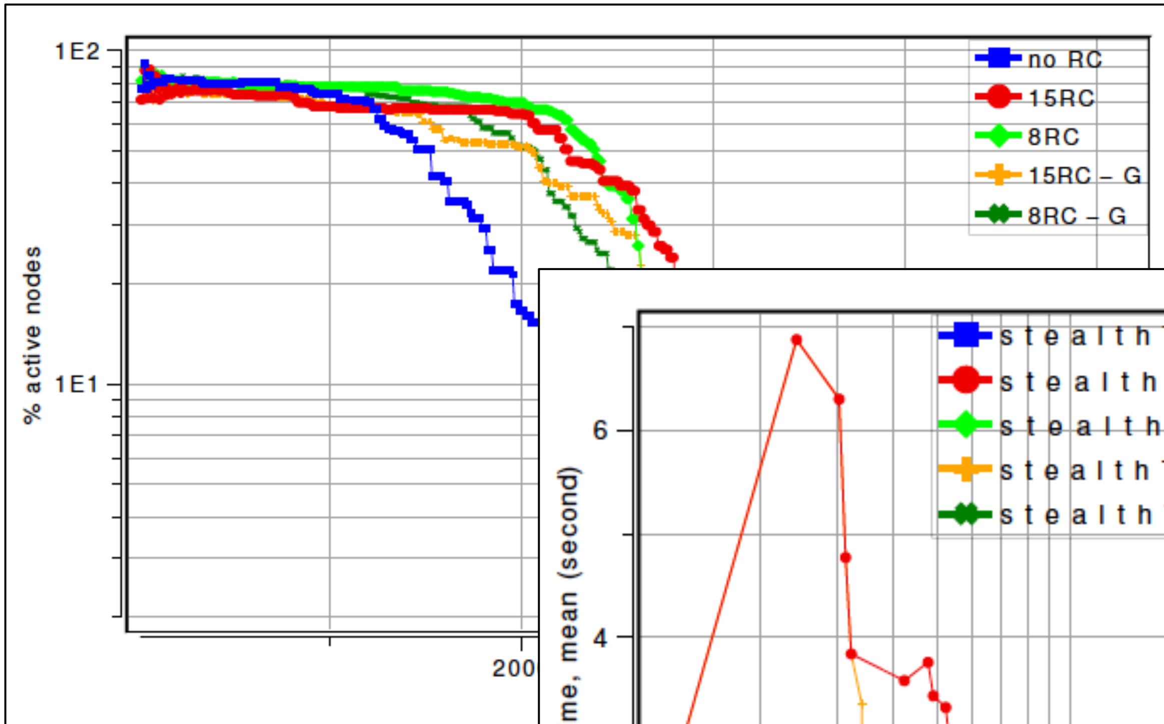
Cooperation with cameras on mobile robots

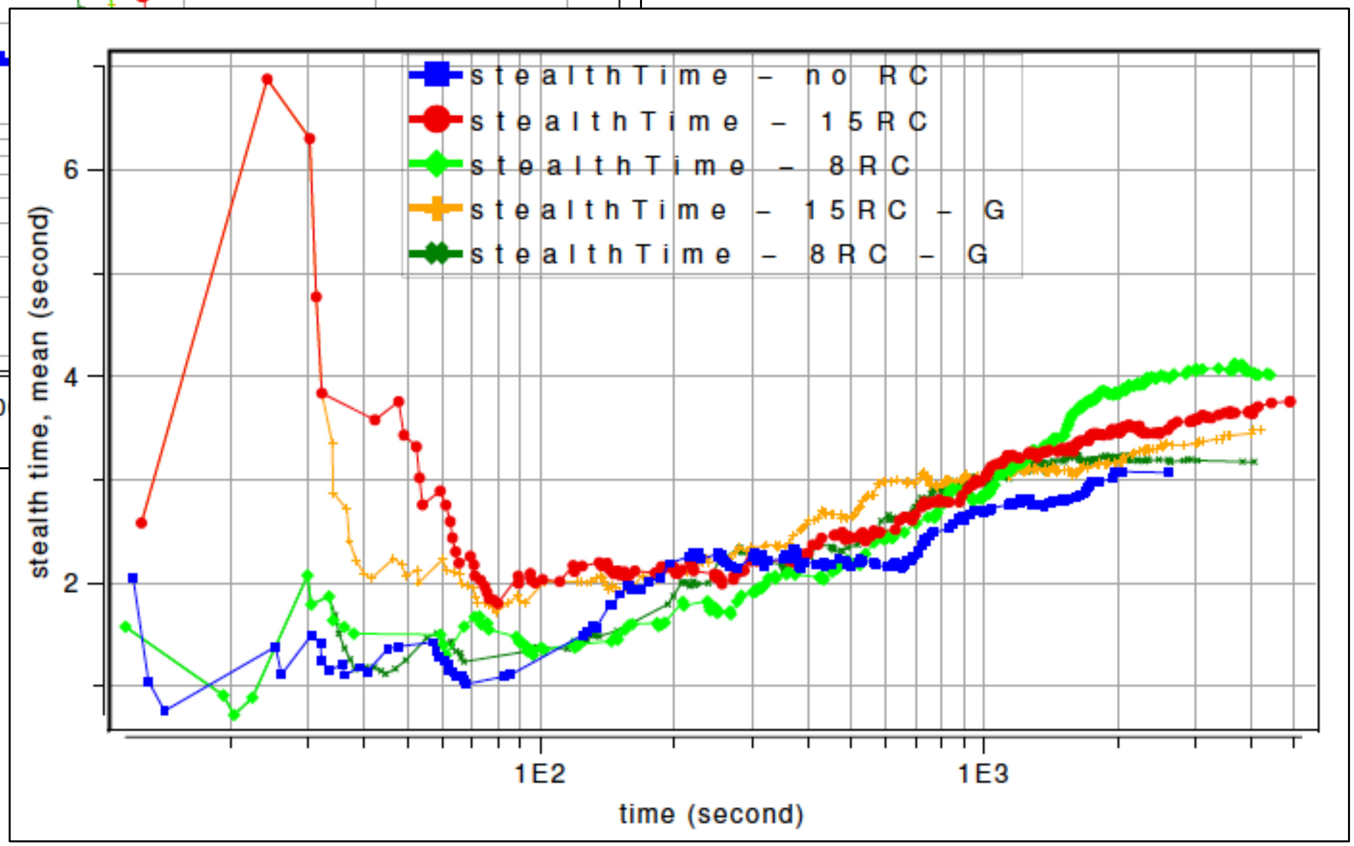
Fixed image sensors near a mobile camera can decrease their criticality level

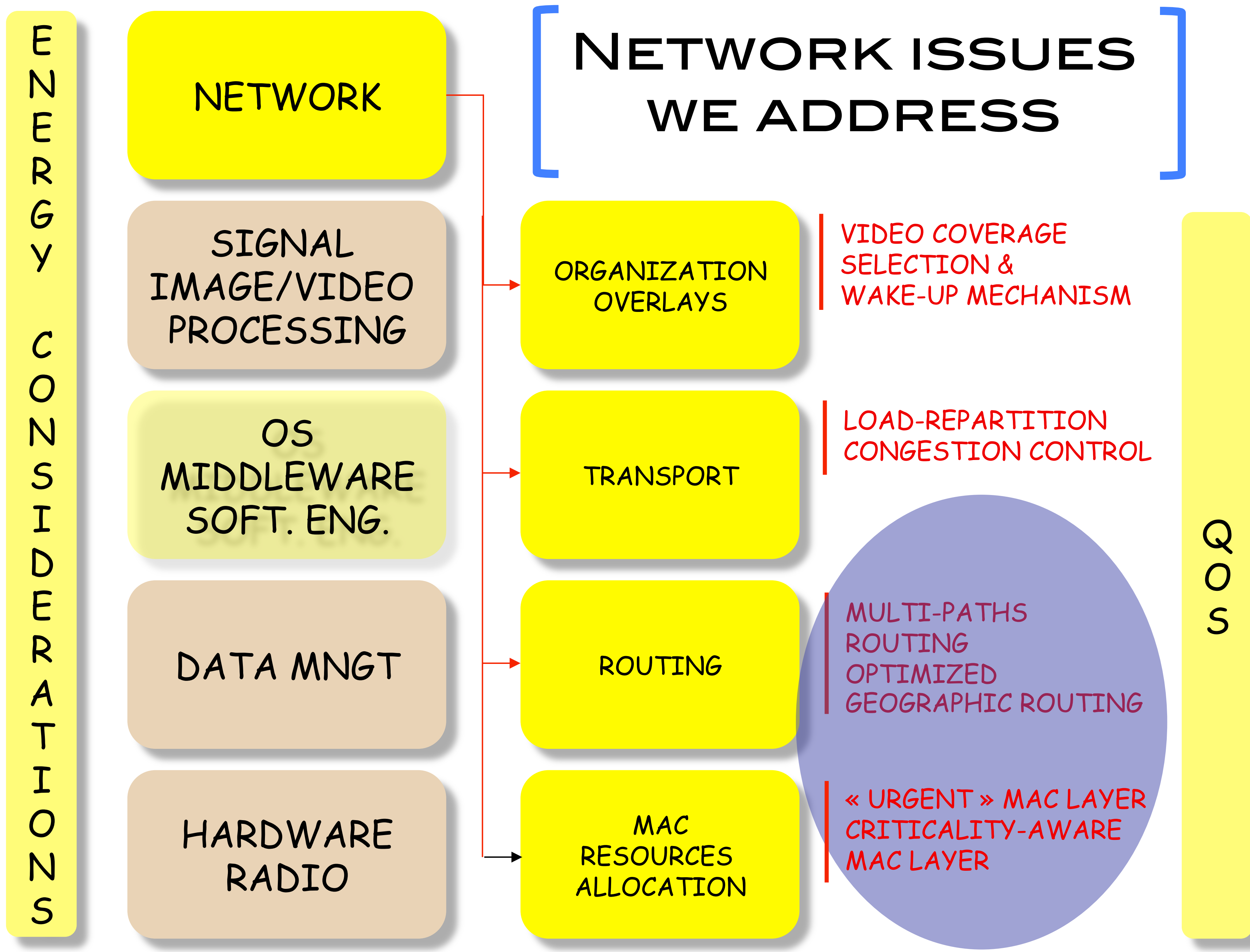
ONLY fixed image sensors whose FoV's center is covered by a mobile camera CAN decrease their criticality level



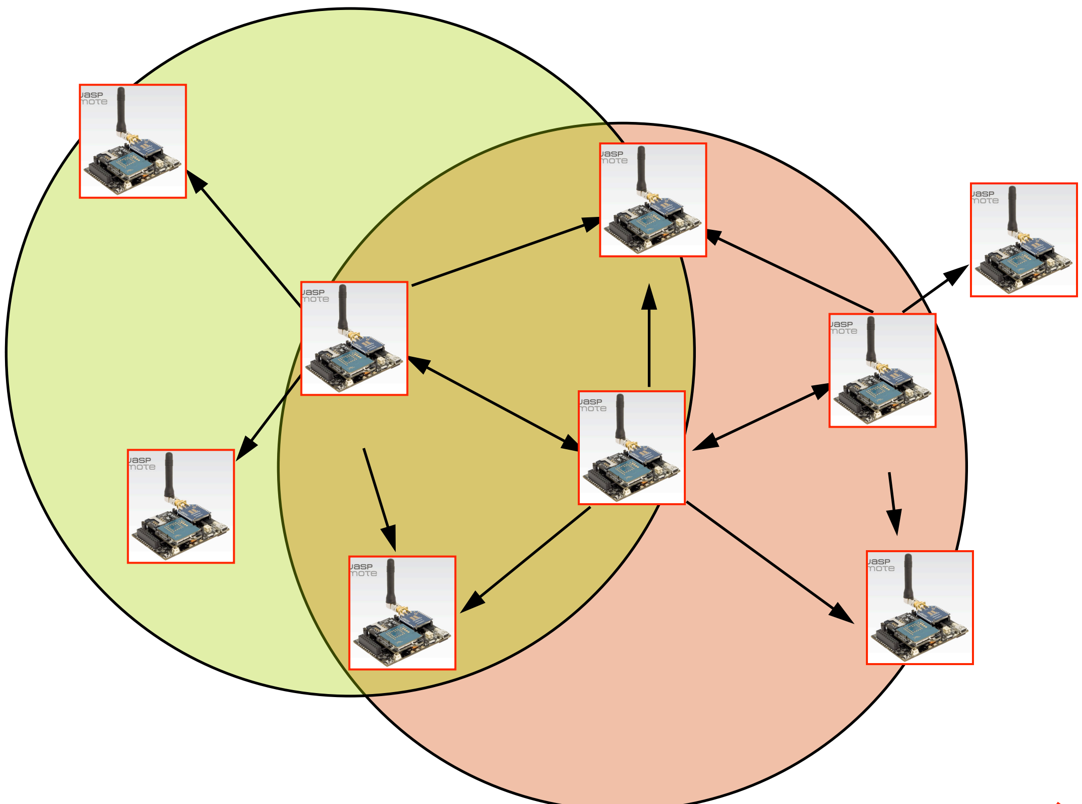
Impact on lifetime & stealth time






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

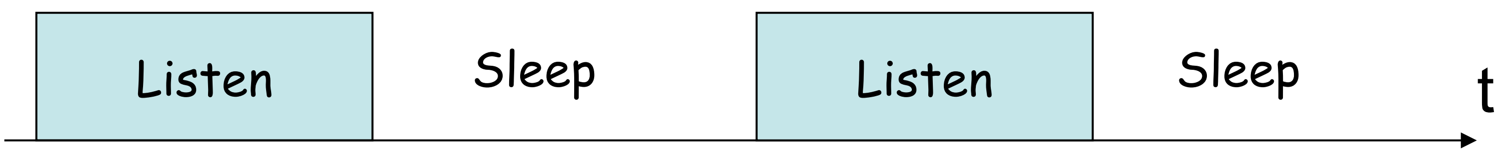
Huge cost of passive listening!

WSN can be idle for a long period!

TDMA is usually not used because of waste of resource

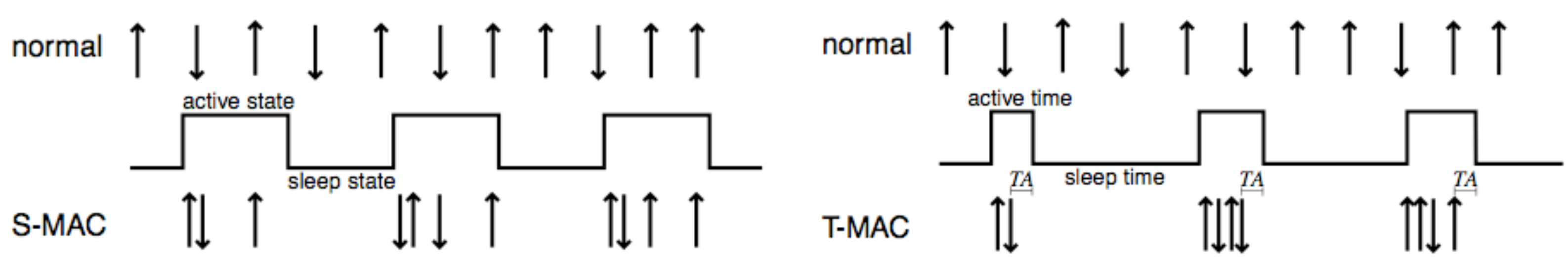
S-MAC - Sensor MAC

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



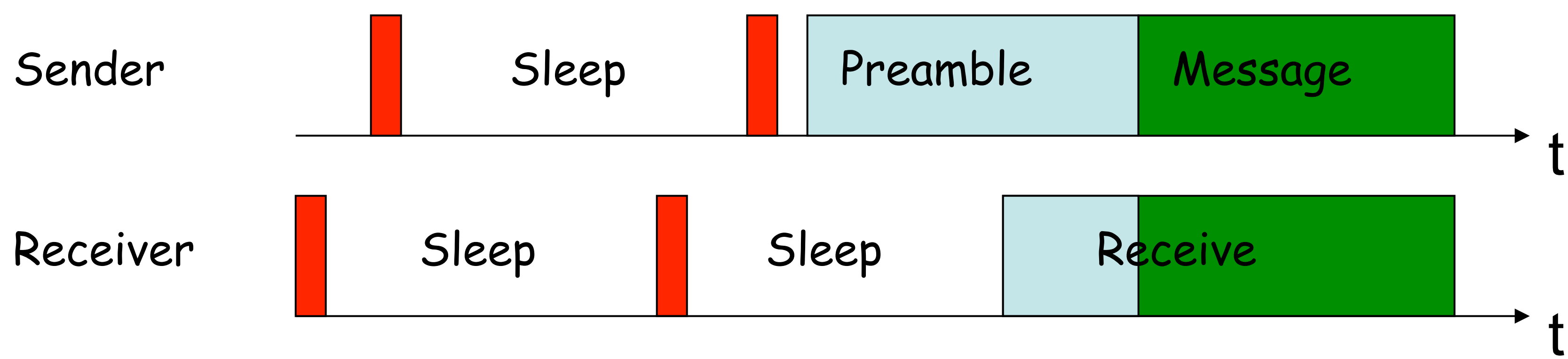
T-MAC - Timeout MAC

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



B-MAC

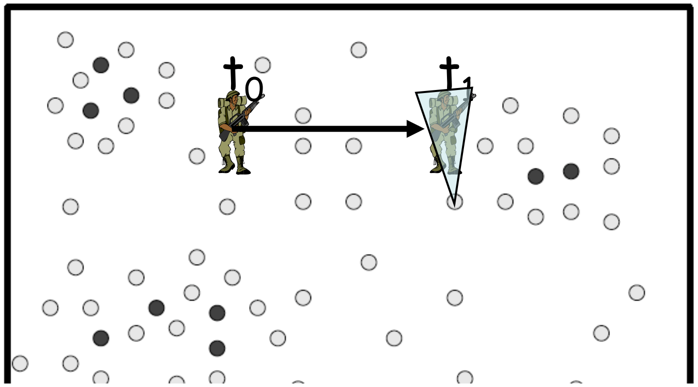
- Low Power Listening (LPL) using preamble sampling
- Hidden terminal and multi-packet mechanisms not provided, should be implemented, if needed, by higher layers



Challenges for MAC protocols in WSN

- Energy efficiency
- Low latencies
- Fairness

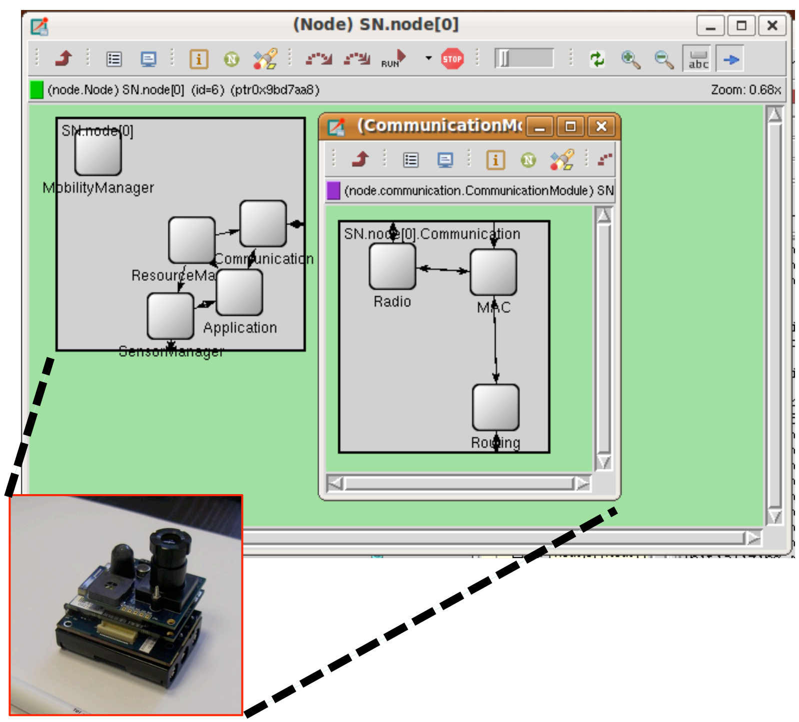
A CHALLENGE FOR MISSION-CRITICAL APPLICATION

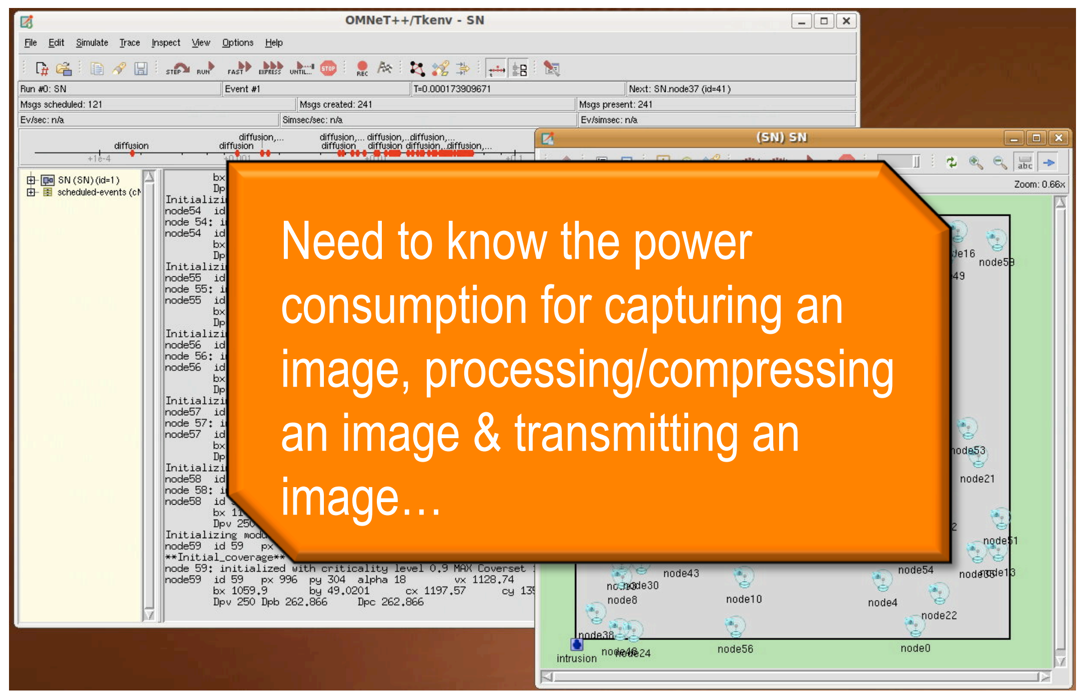


Simulation Tools

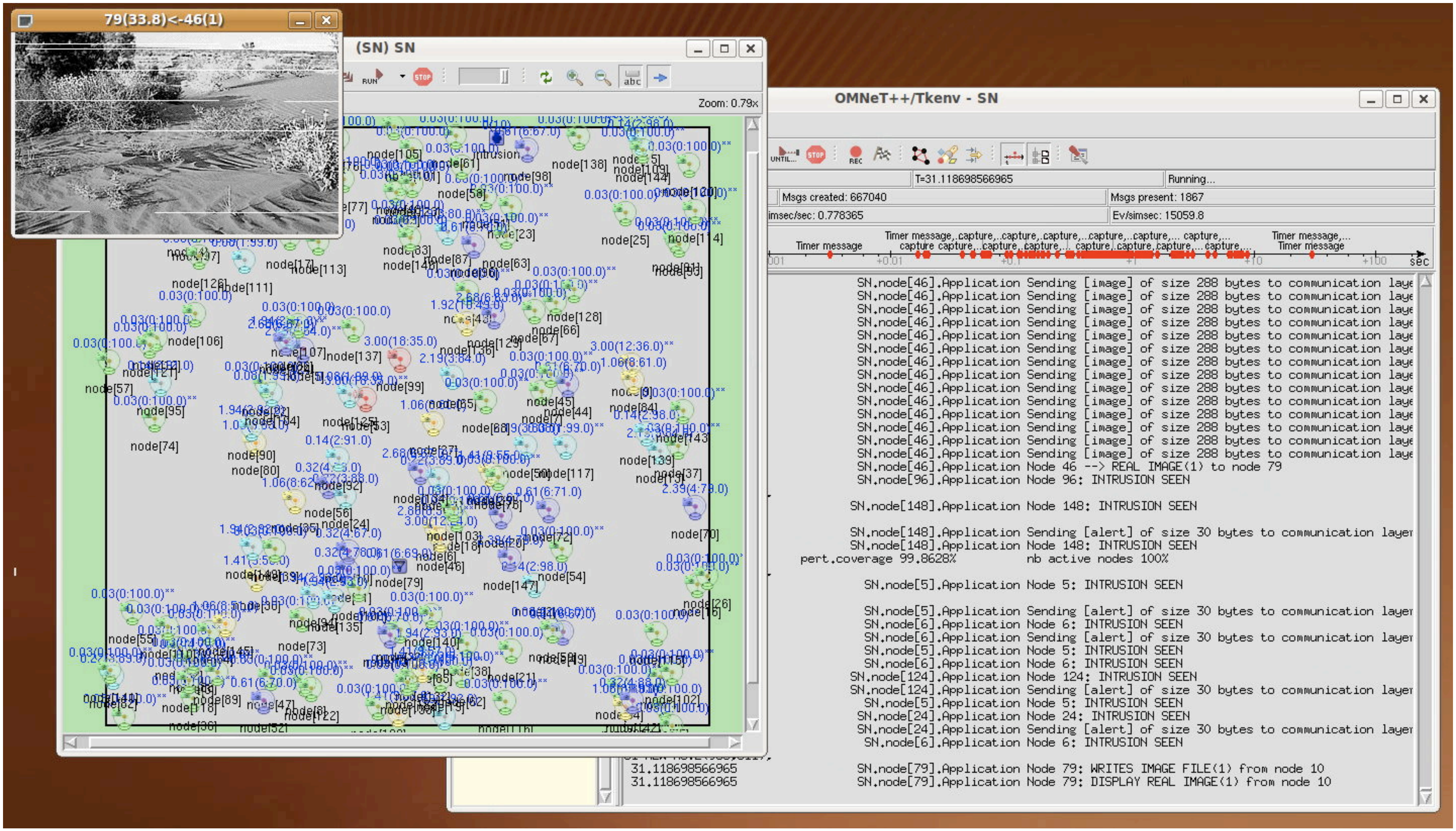
Image sensor simulation model under OMNET++

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



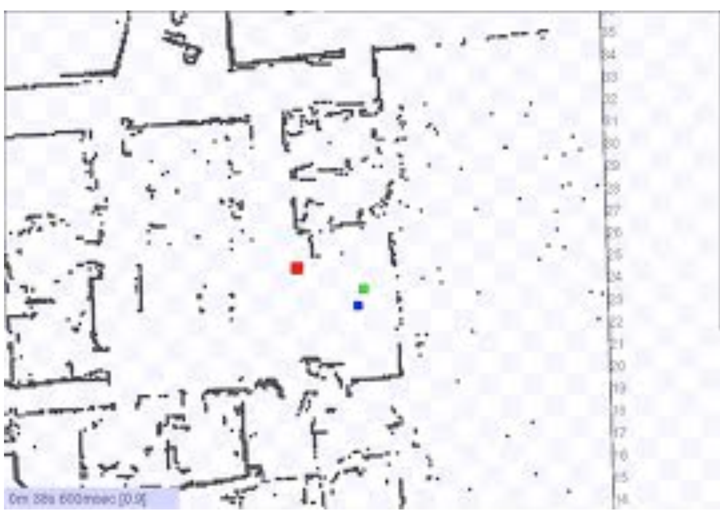


Study the impact of communication layer on surveillance quality



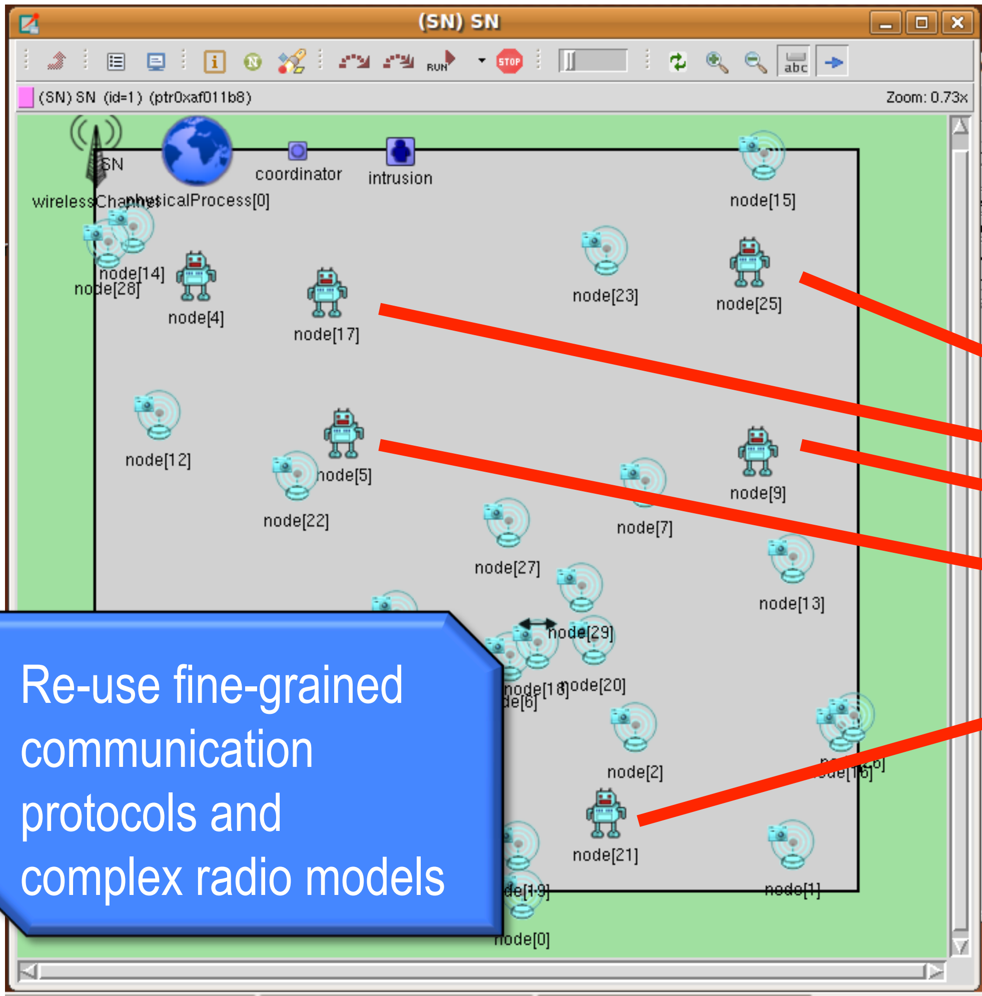
Robot simulators

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

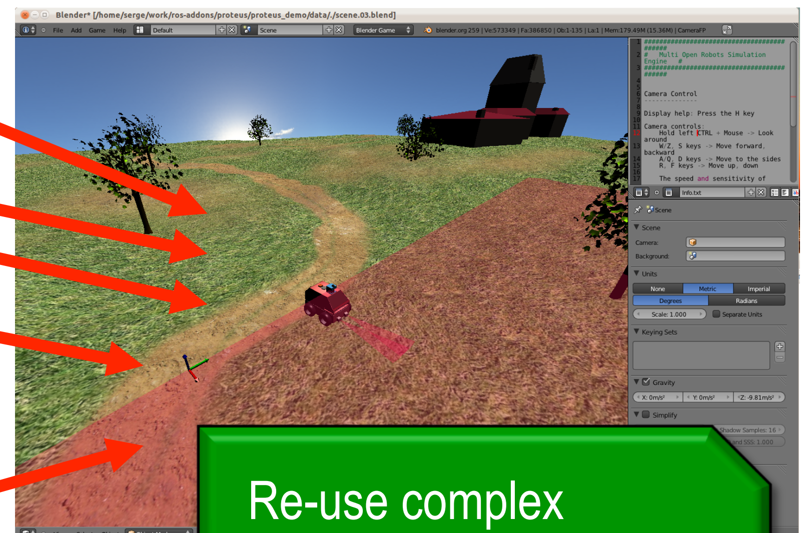


[Sensors & Robots enable realistic interaction studies]

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,…)

Research collaboration

- Visual sensors and robots introduces new interaction schemes but reliability/quality of images are of utmost importance
- Routing and Mac layers are layers in these applications
- Image encoding techniques can contribute to improve image robustness
- Issues:
  - Impacts of losses on image quality?
  - New encoding techniques for sensor-robots?