Deployment of video surveillance applications on wireless sensor networks: challenges & research directions

University of Oran Es-Sénia

Wednesday, november 25th, 2009

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Université de Pau, France

Déploiement d'applications de surveillance vidéo sur réseaux de capteurs sans-fils:

Défis et pistes de recherche

Université d'Oran Es-Sénia
Mercredi 25 novembre 2009

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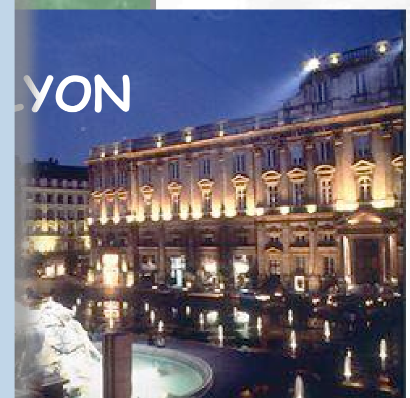
Préambule

parallel simulation of large-scale communication networks, cluster computing

Multicast, active & programmable networks, smart GRID systems

Transport and congestion control for very large pipes

Sensor networks, surveillance & critical applications



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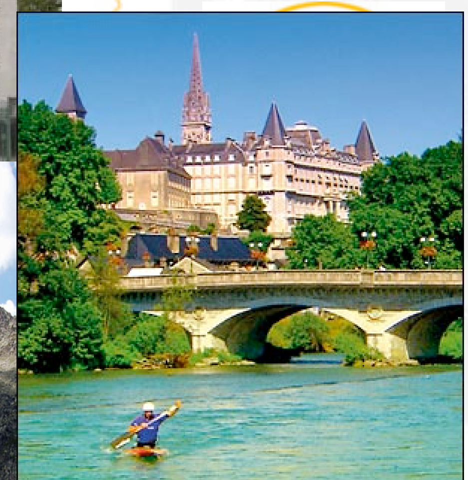

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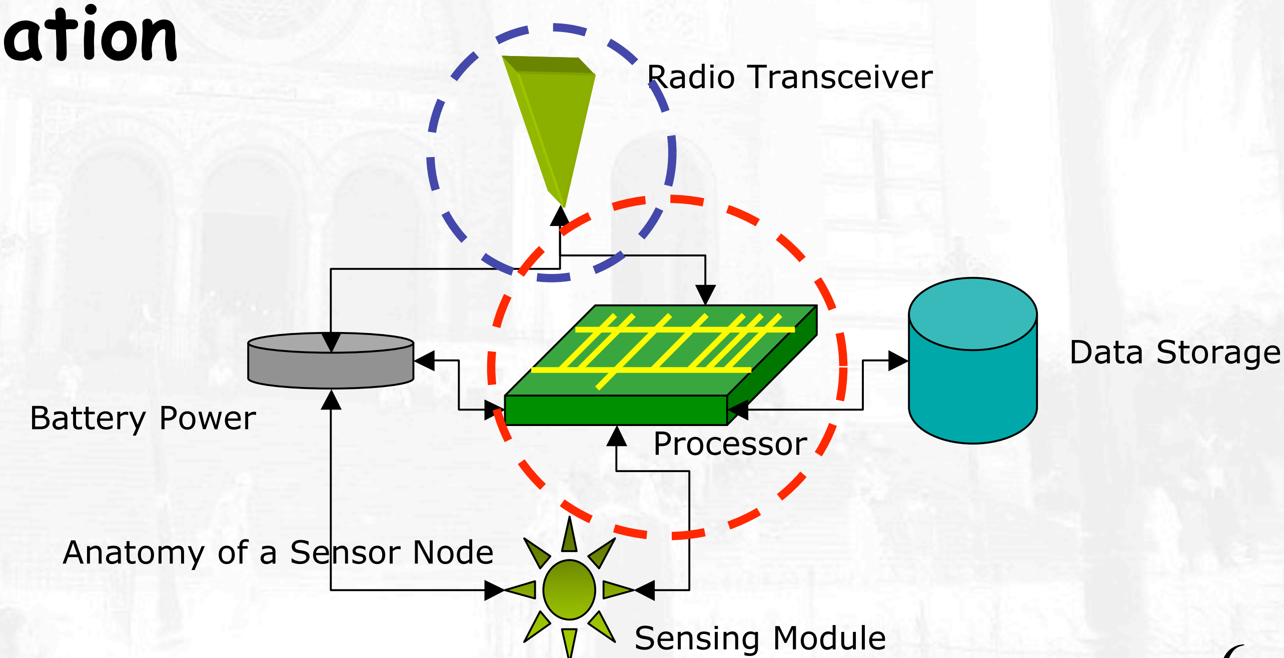
LIUPPA

- **COMPUTER SCIENCE LAB**
  - **32 FACULTY MEMBERS**
  - **25 PHD STUDENTS**
- **2 RESEARCH TEAMS**
  - **MODELING, VISUALIZATION, EXECUTION & SIMULATION**
  - **INFORMATION PROCESSING, INTERACTIONS AND ADAPTATION**
- **DIRECTOR FROM 2006 TO 2009**

Wireless autonomous sensor

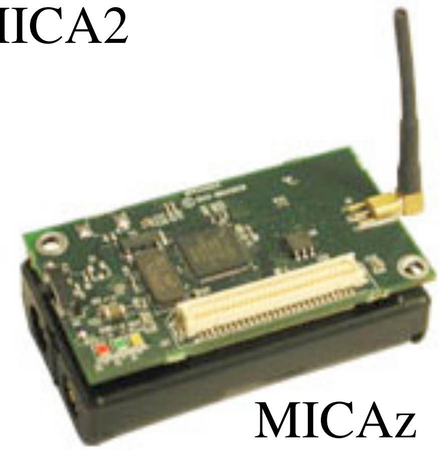
- In general: low cost, low power (the battery may not be replaceable), small size, prone to failure, possibly disposable
- Role: sensing, **data processing**, **communication**



Berkeley Motes (contd.)

- Each Mote has two separate boards
  - A main CPU board with radio communication circuitry
  - A secondary board with sensing circuitry
- Decouples sensing hardware from communication hardware
- Allows for customization since application specific sensor hardware can be plugged-on to the main board

MICA2



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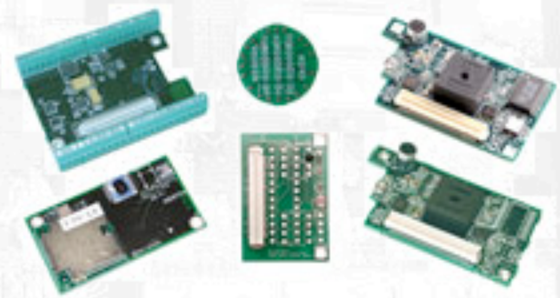
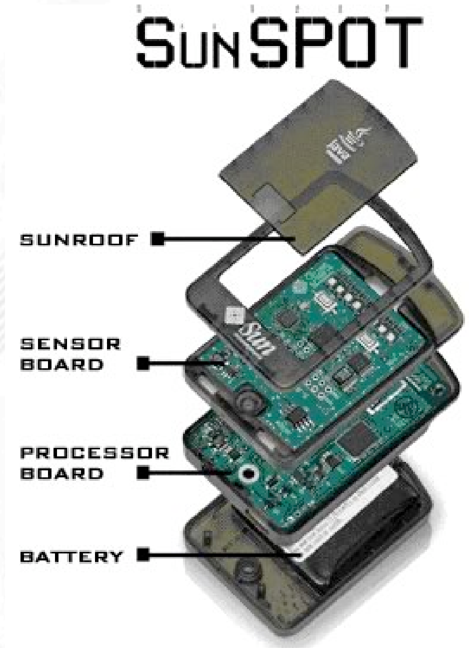
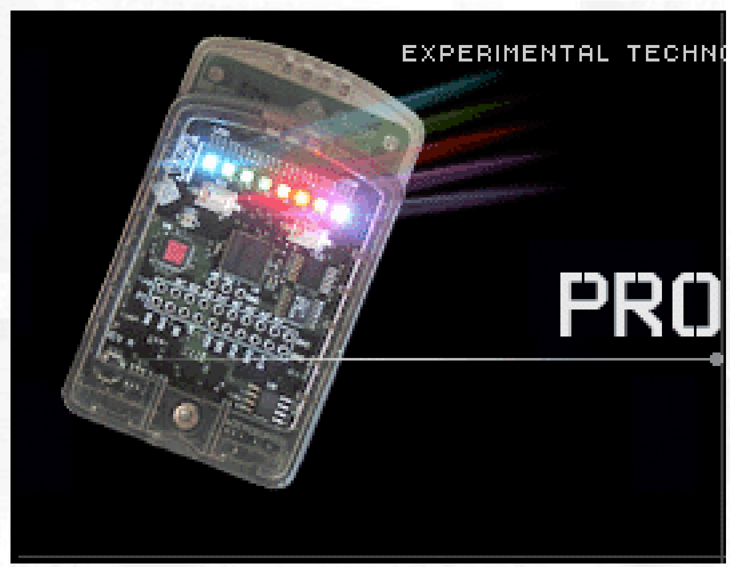


Sensing boards

SUN SPOT

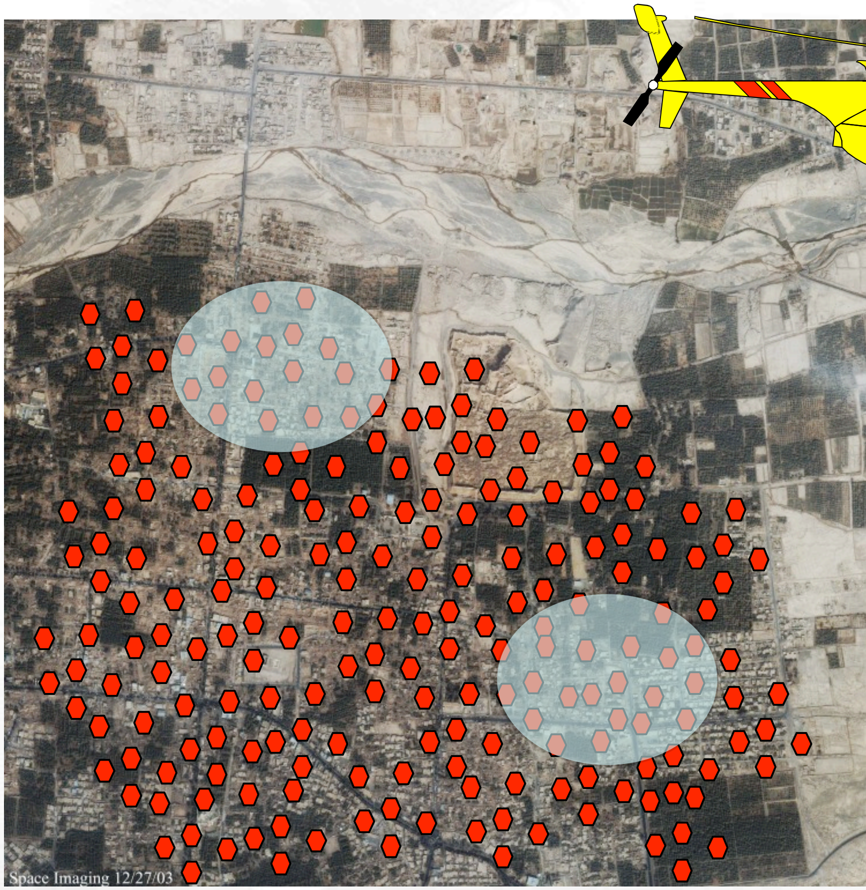
- Processor : ARM920T 180MHz 32-bit
- 512K RAM & 4M Flash.
- Communication : 2.4GHz, radio chipset: TI CC2420 (ChipCon) – IEEE 802.15.4 compatible
- Java Virtual Machine (Squawk)
- LIUPPA is official partner

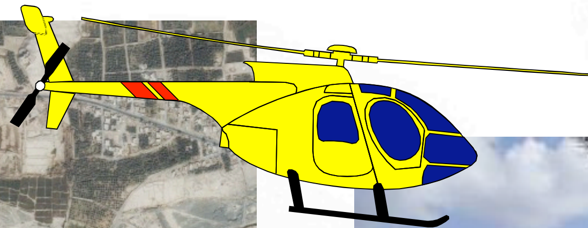




Sensor network=monitoring

disaster relief - security





Real-time organization and optimization of rescue in large scale disasters

Rapid deployment of fire detection systems in high-risk places

Sensor as common object
toward very large scale deployment

Environmental monitoring
- air
- water

Cell-phones with embedded CO sensor

- most ubiquitous device (millions)
- not deployment cost
- high replacement rate
- no energy constraints

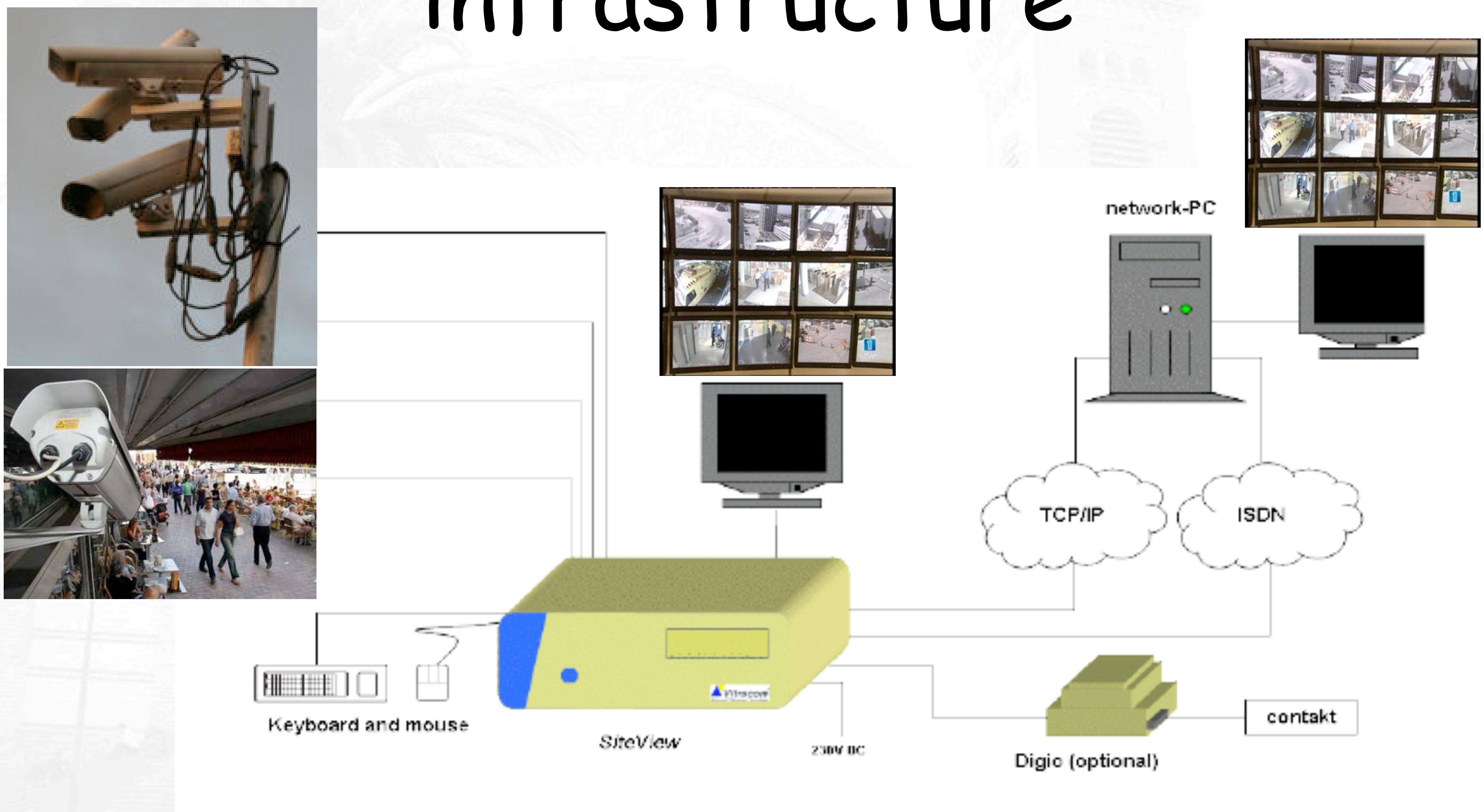
TCAP project (2006-2009)

- « Video Flows Transport for Surveillance Application »
- LIUPPA
  - Software architecture for multimedia integration, supervision plateform, transport protocols & congestion control
- CRAN (Nancy)
  - Video coding techniques, multi-path routing, interference-free routing

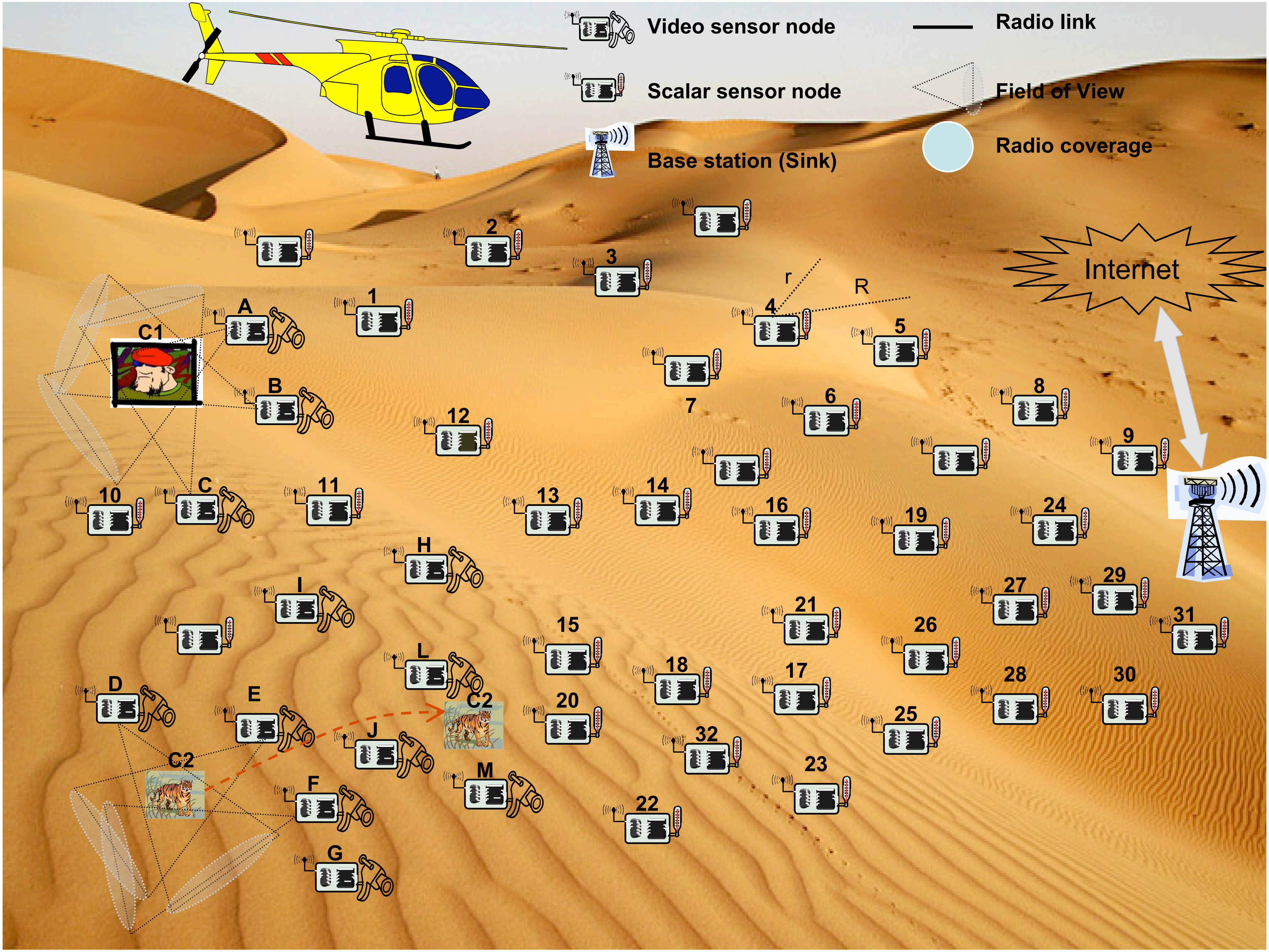
PHC Tassili (2009-2012)

- « Contrôle coopératif dans les réseaux de capteurs sans-fils pour la surveillance »
- LIUPPA (Pau)
  - Congduc Pham
- CRAN (Nancy)
  - Moufida Maimour
- U. Oran-Es Senia
  - H. Haffaf, B. Kechar,…

Traditionnal surveillance infrastructure



Vitracom®
Advanced Videosensor Technologies



Video sensor node
Scalar sensor node
Base station (Sink)
Radio link
Field of View
Radio coverage
Internet
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B
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C1
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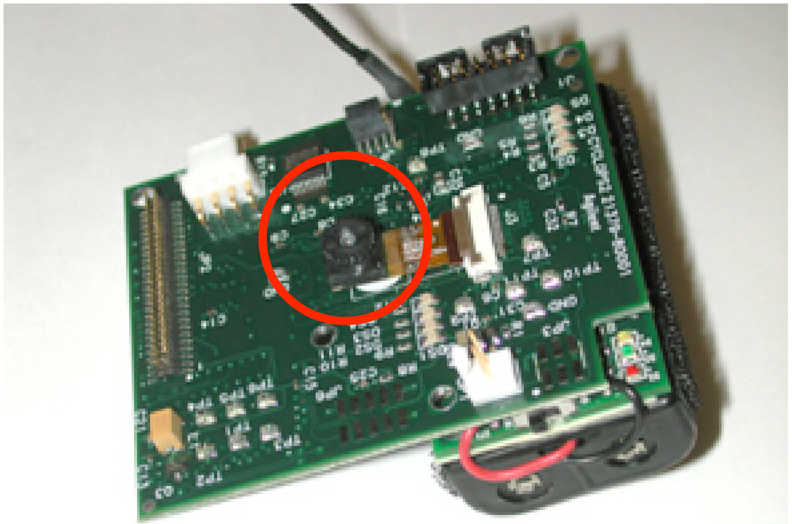
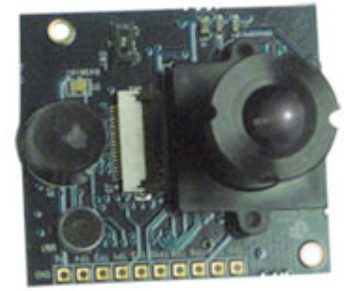
Wireless Video Sensors

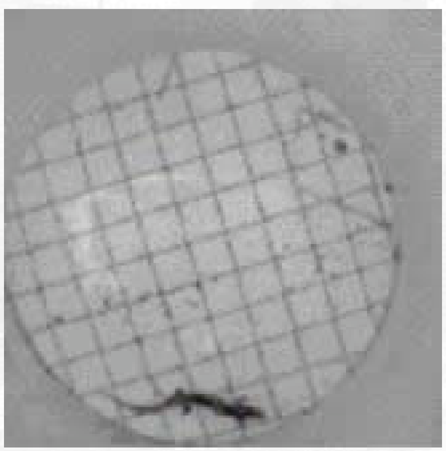


Cyclops video board on Mica motes

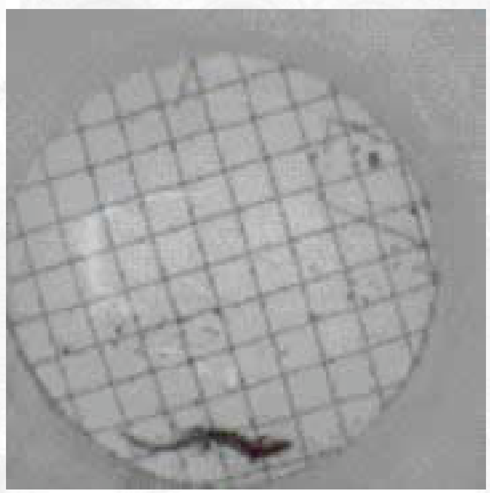
Imote2



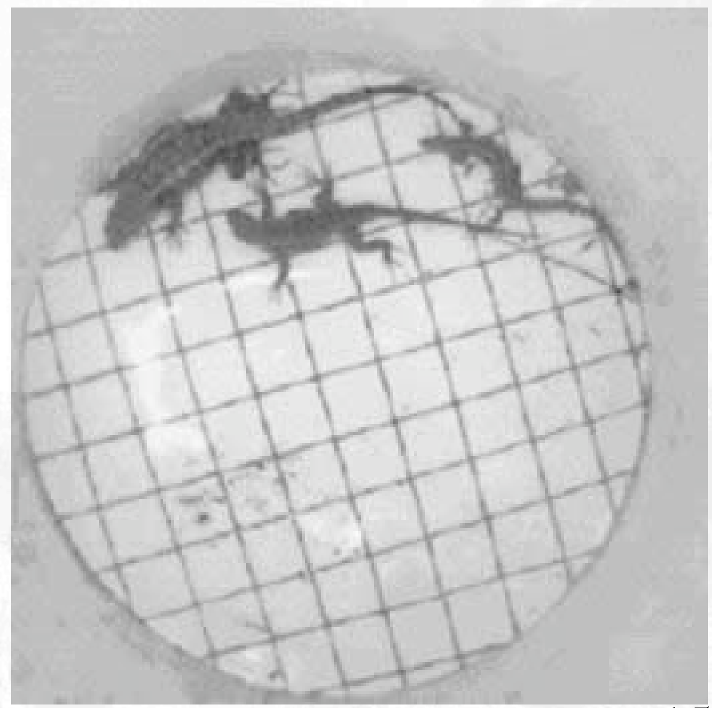
Multimedia board



128x128



140x140

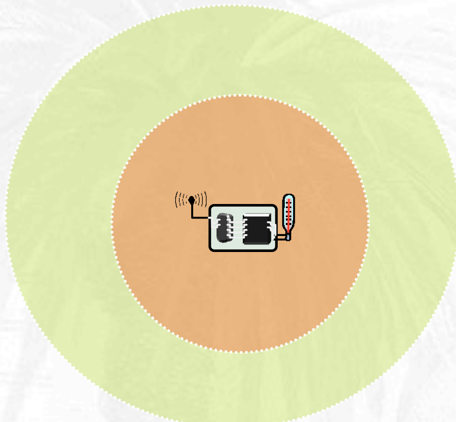


240x240

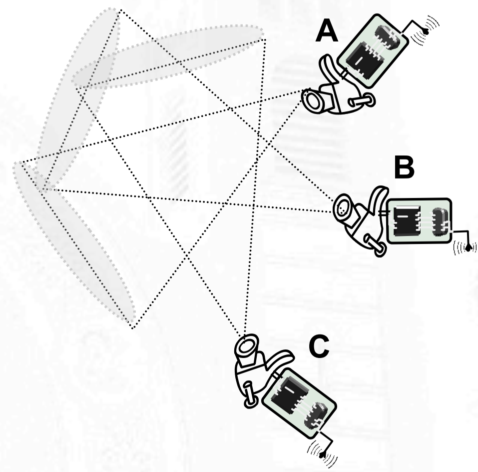
Challenges?

- Wireless Scalar Sensor Networks
  - Small size of events (°C, pressure,…)
  - Usually no mobility
  - Data fusion, localization, routing, congestion control
- Wireless Video Sensor Networks
  - Video needs much higher data rate
  - Sensing range is a cone of vision
- WVSN for Surveillance
  - What's new?
  - Where are the challenges?

Sensing range & coverage



vs



Video sensors capture scene with a Field of View
~ a cone

Zoom feature = Depth of View

Image resolution, capture speed, rotation,...

Surveillance applications (1)

- Lesson 1: don't miss important events

What is captured

Whole understanding of the scene is wrong!!!

Surveillance applications (2)

- Lesson 2: high-quality not necessarily good

333x358 16M colors, no light

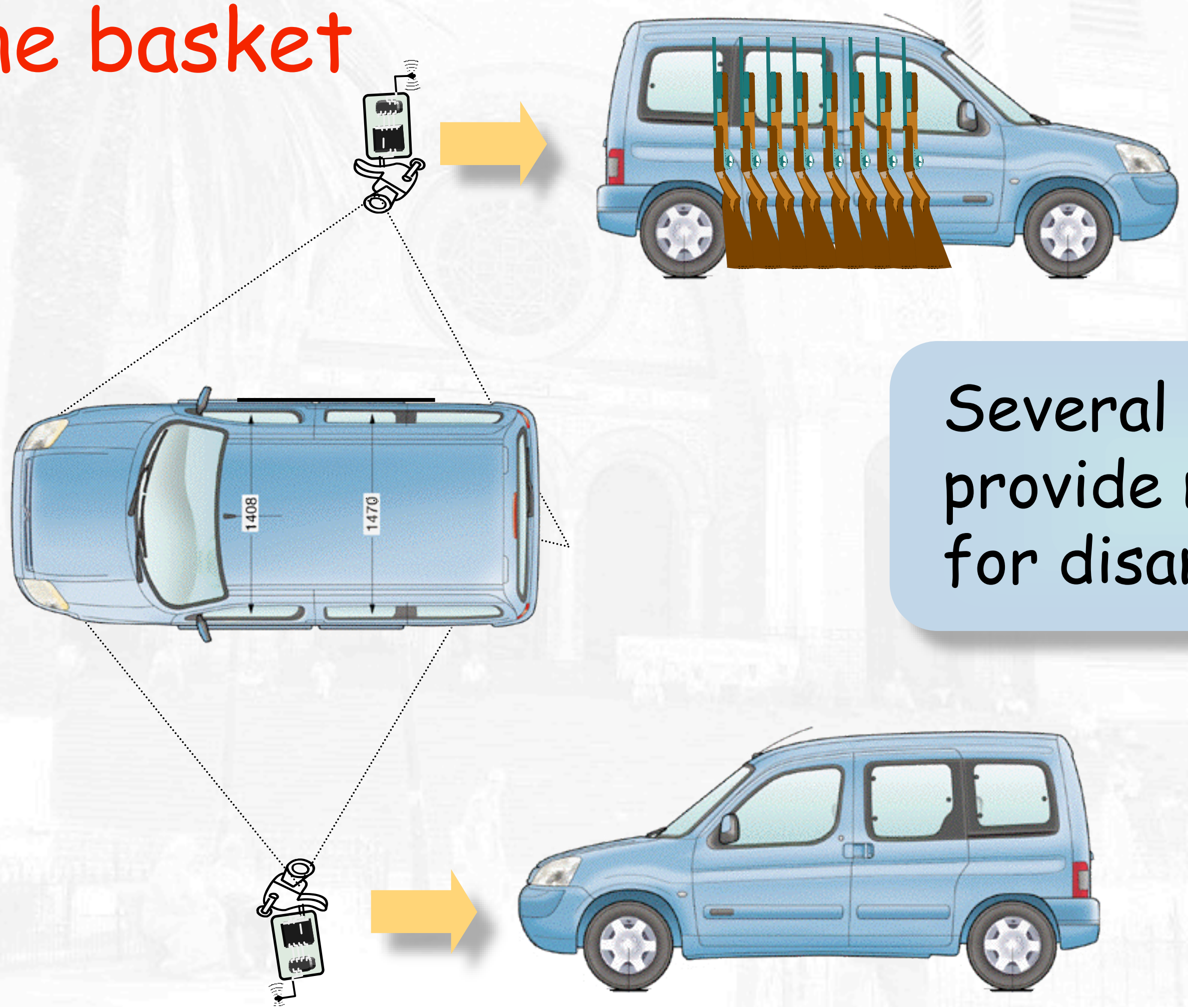
167x180 16 colors, light

Keep in mind the goal of the application!

167x180 BW (2 colors), light

Surveillance applications (3)

- Lesson 3: don't put all your eggs in one basket



Several camera provide multi-view for disambiguation

Surveillance: a critical app!

- Availability: 24/24 surveillance
  - Failures: energy-efficient algorithms & protocols
  - Scheduling
- Quality
  - Enhance/validate/disambiguate video information with other sources of information
  - Replace video by infrared when it's dark
  - If critical, why not « kamikaze » flash-sensor?
- Reliability/integrity
  - Monitor the network itself
  - Are the information sent consistent?

Surveillance Service

ACCOUNTABILITY

- Similar to Service Level Agreement

→ **SURVEILLANCE AT ANY PRICE** ←

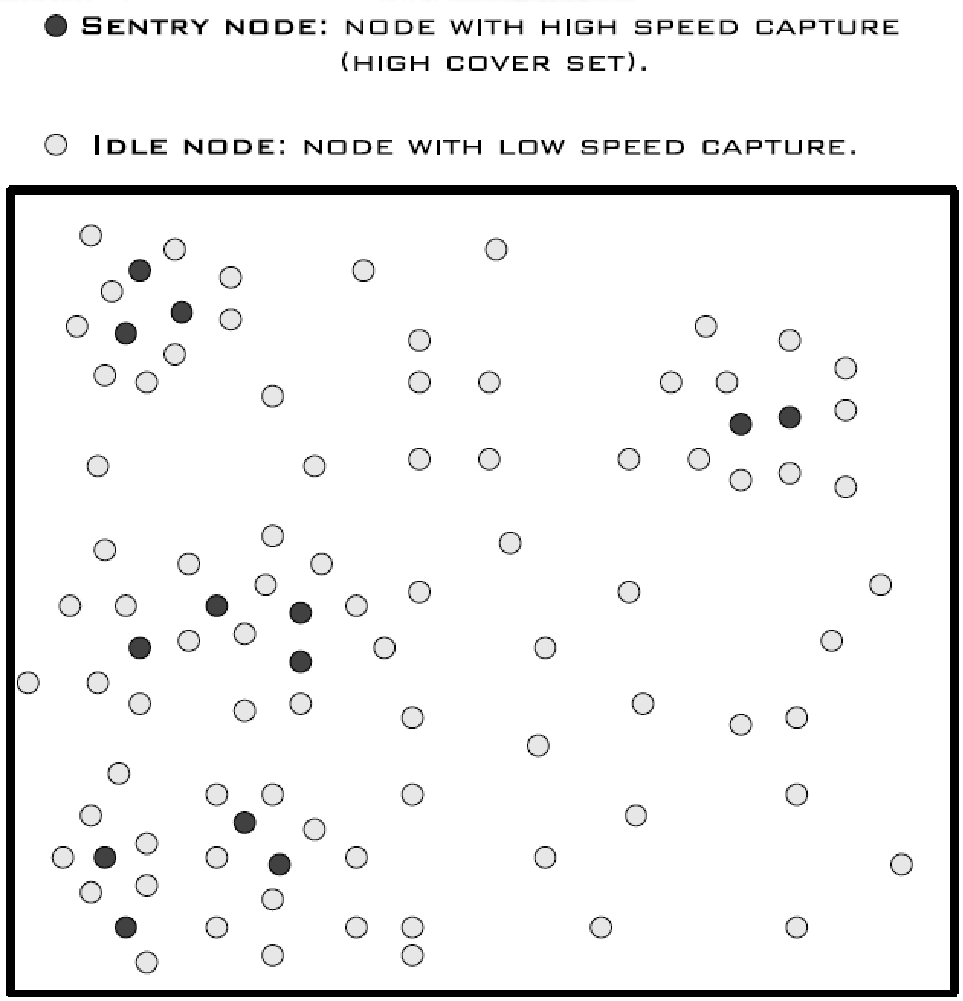
no discontinuity of service against node's failures

collaborative sensors

service independant of its implementation

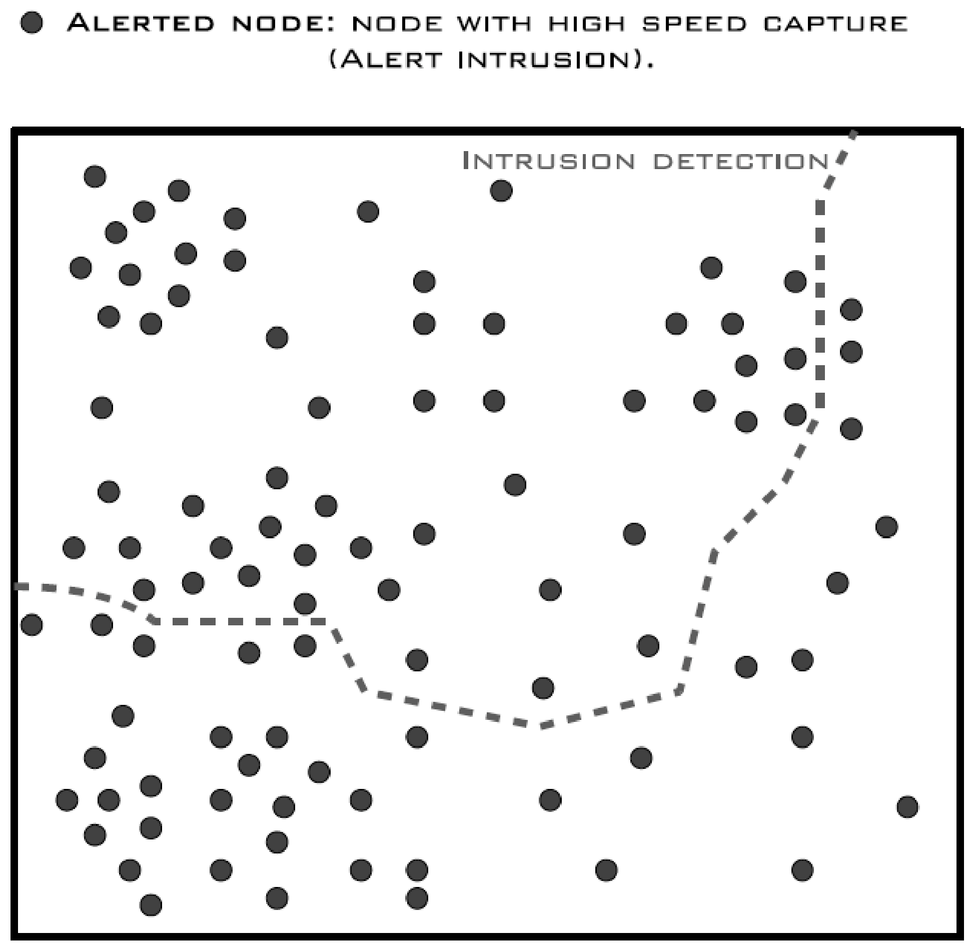
Surveillance scenario (1)

- Randomly deployed video sensors
- Not only barrier coverage but general intrusion detection
- Most of the time, network in so-called *hibernate mode*
- Most of active sensor nodes in *idle mode* with low capture speed
- Sentry nodes with higher capture speed to quickly detect intrusions



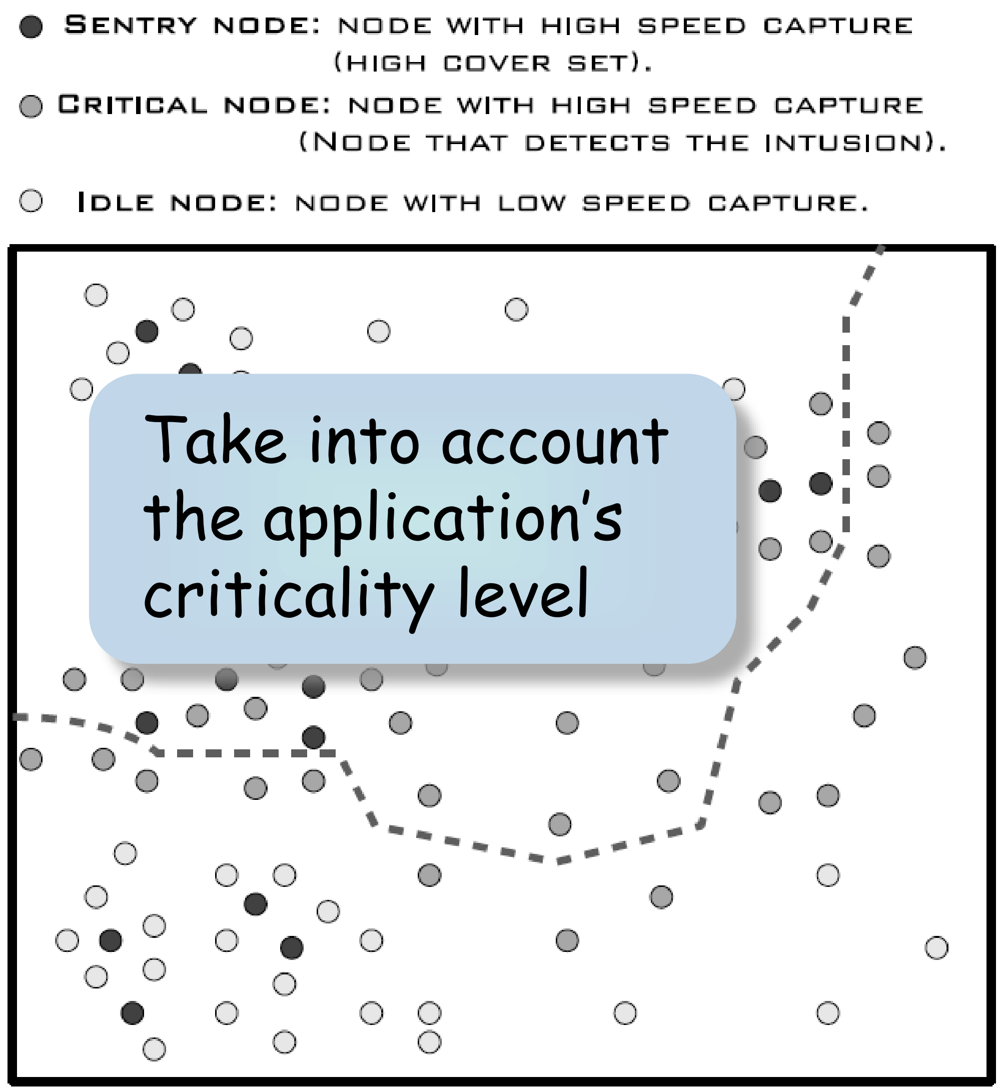
Surveillance scenario (2)

- Nodes detecting intrusion must alert the rest of the network
- 1-hop to k-hop alert
- Network in so-called *alerted mode*
- Capture speed must be increased
- Ressources should be focused on making tracking of intruders easier



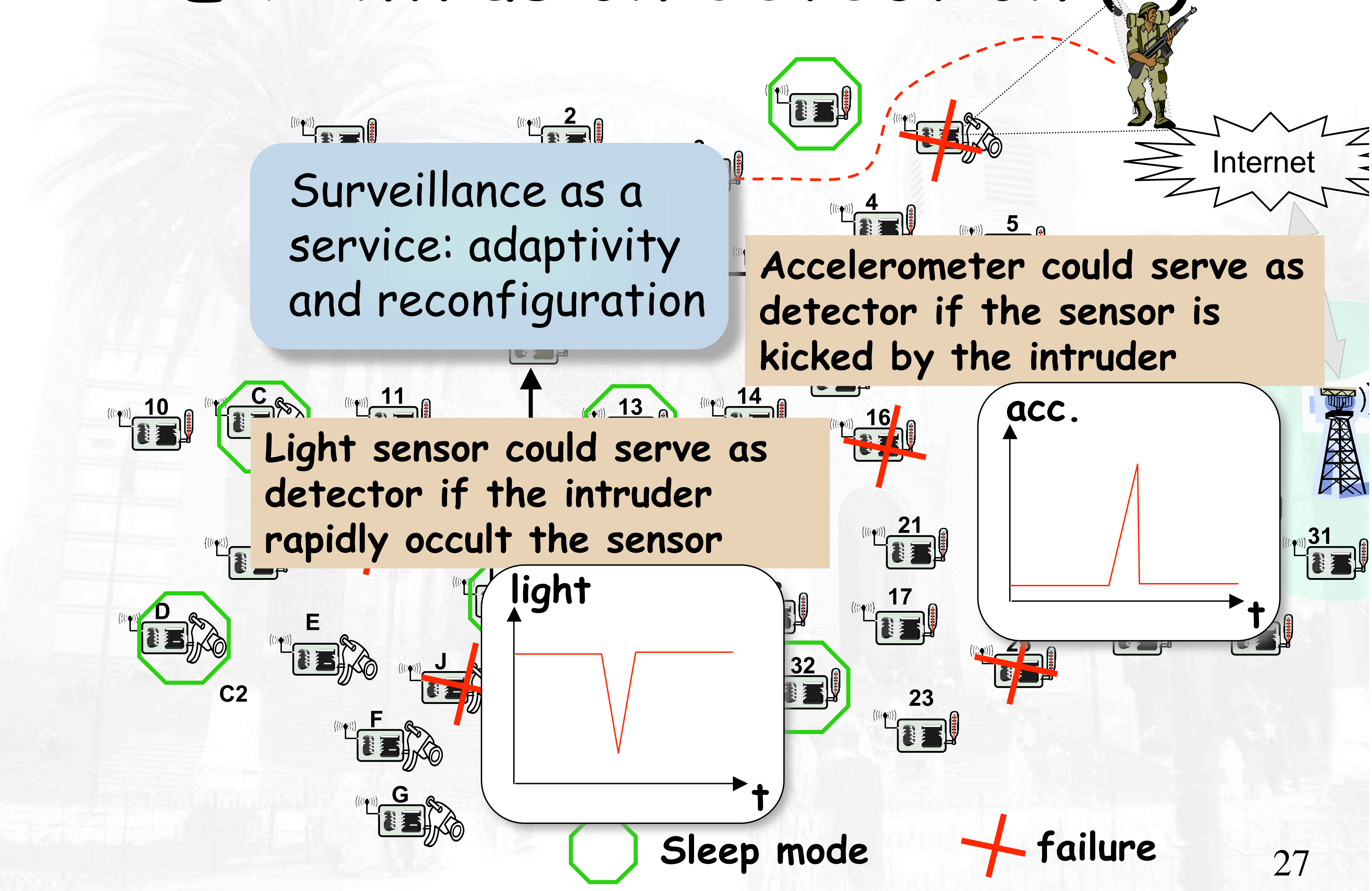
Surveillance scenario (3)

- Network should go back to *hibernate mode*
- Nodes on the intrusion path must keep a high capture speed
- Sentry nodes with higher capture speed to quickly detect intrusions

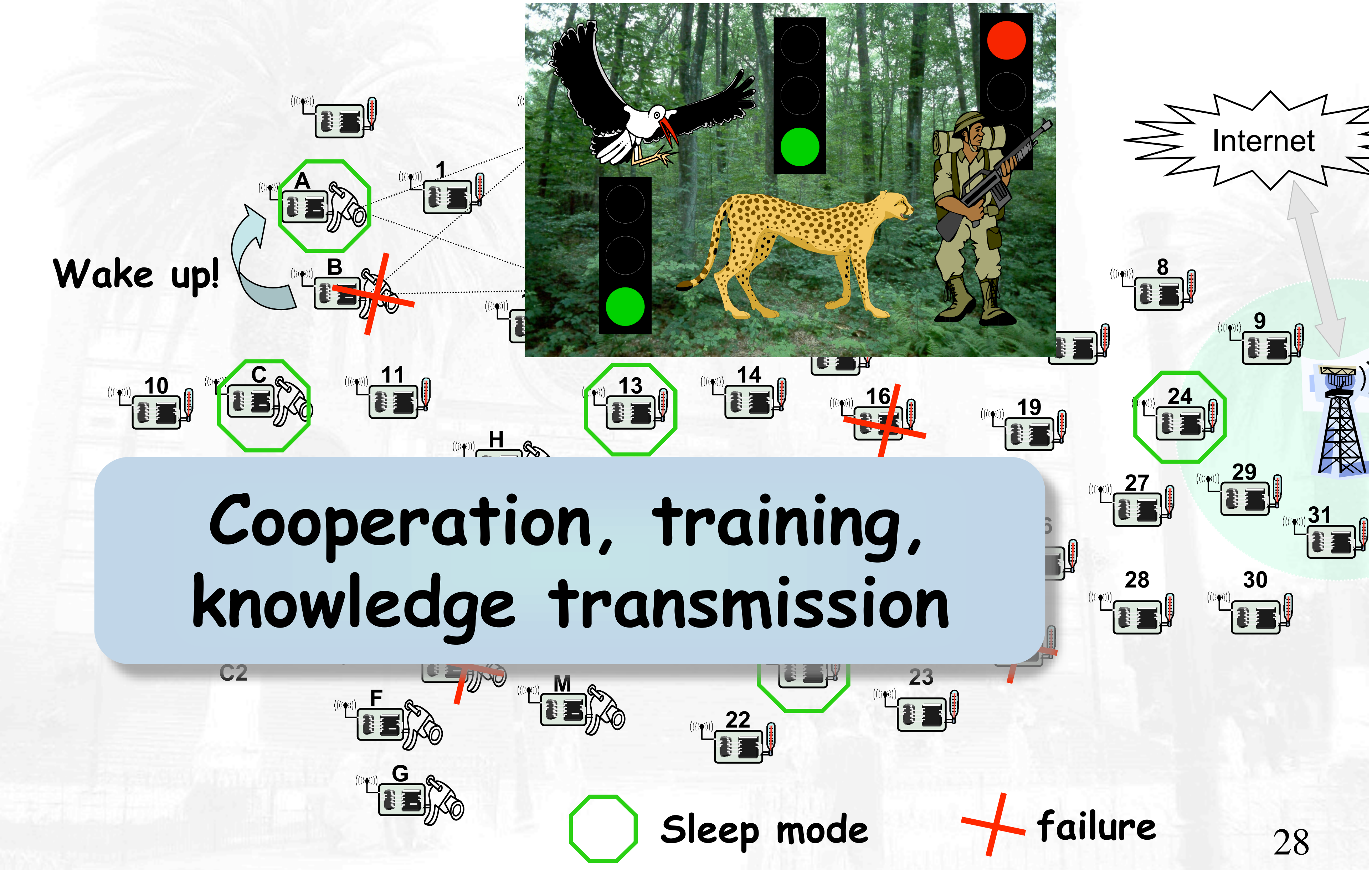


Take into account the application's criticality level

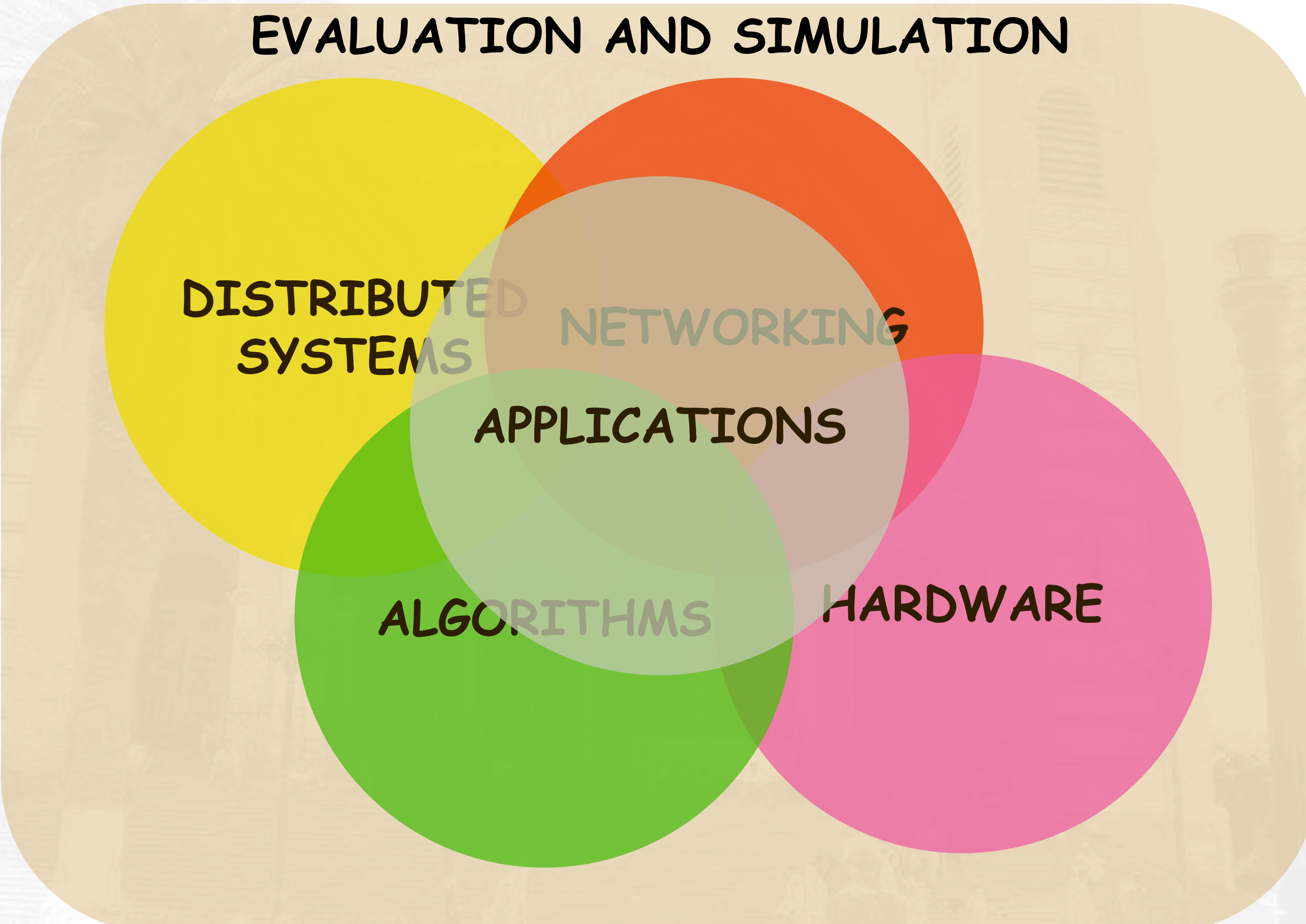
Ex: intrusion detection (1)



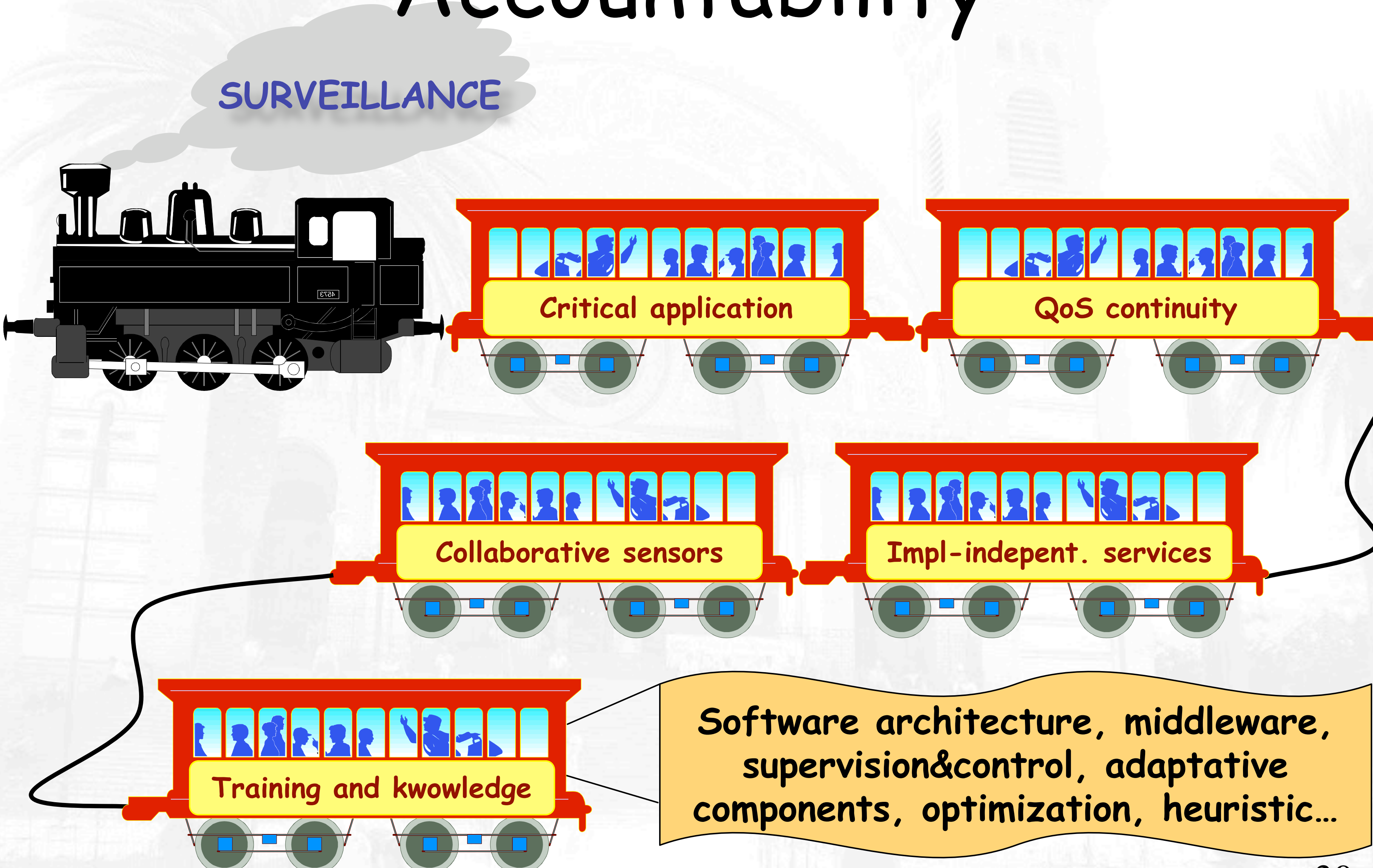
Ex: intrusion detection (2)



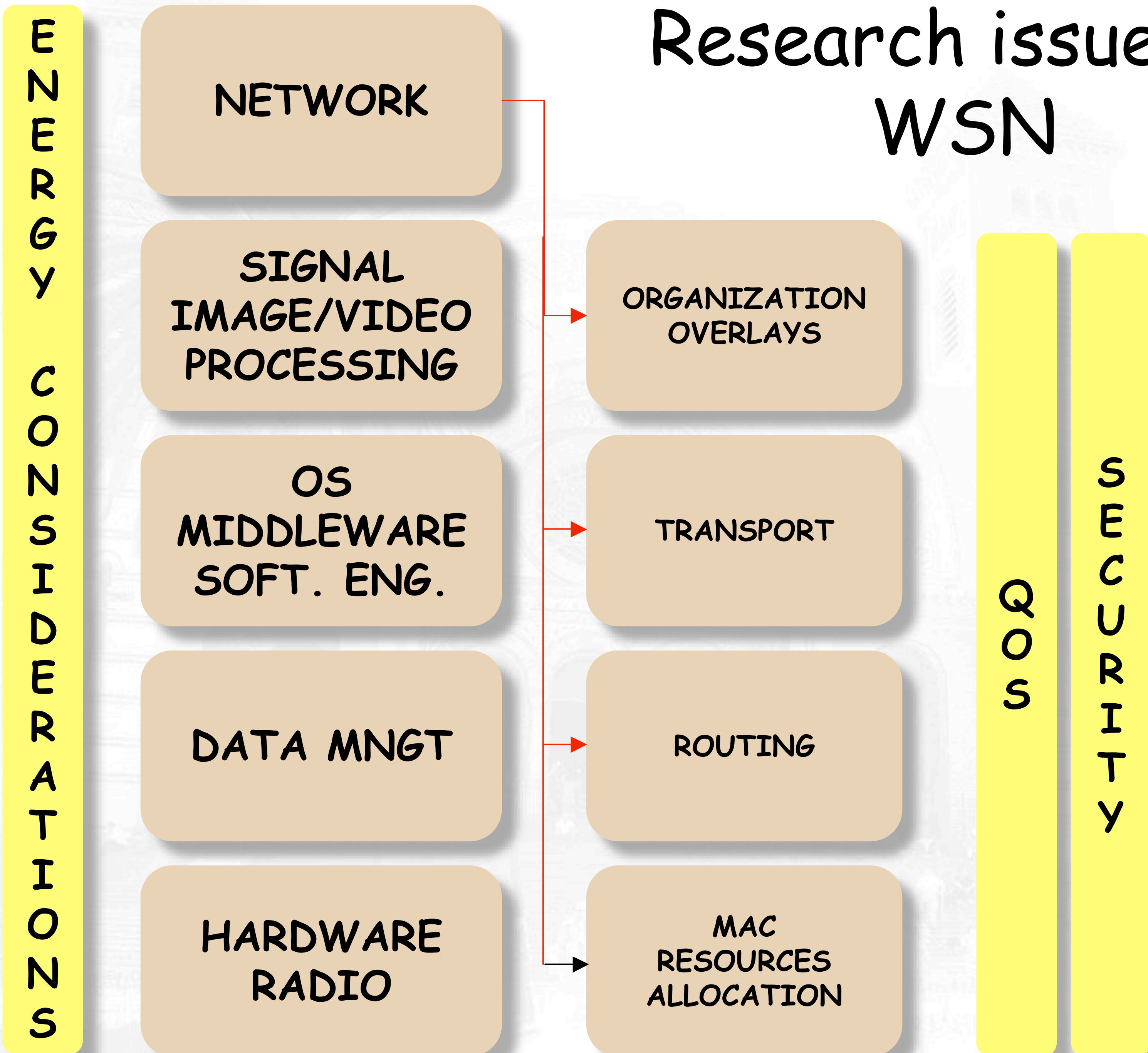
Multidisciplinary research



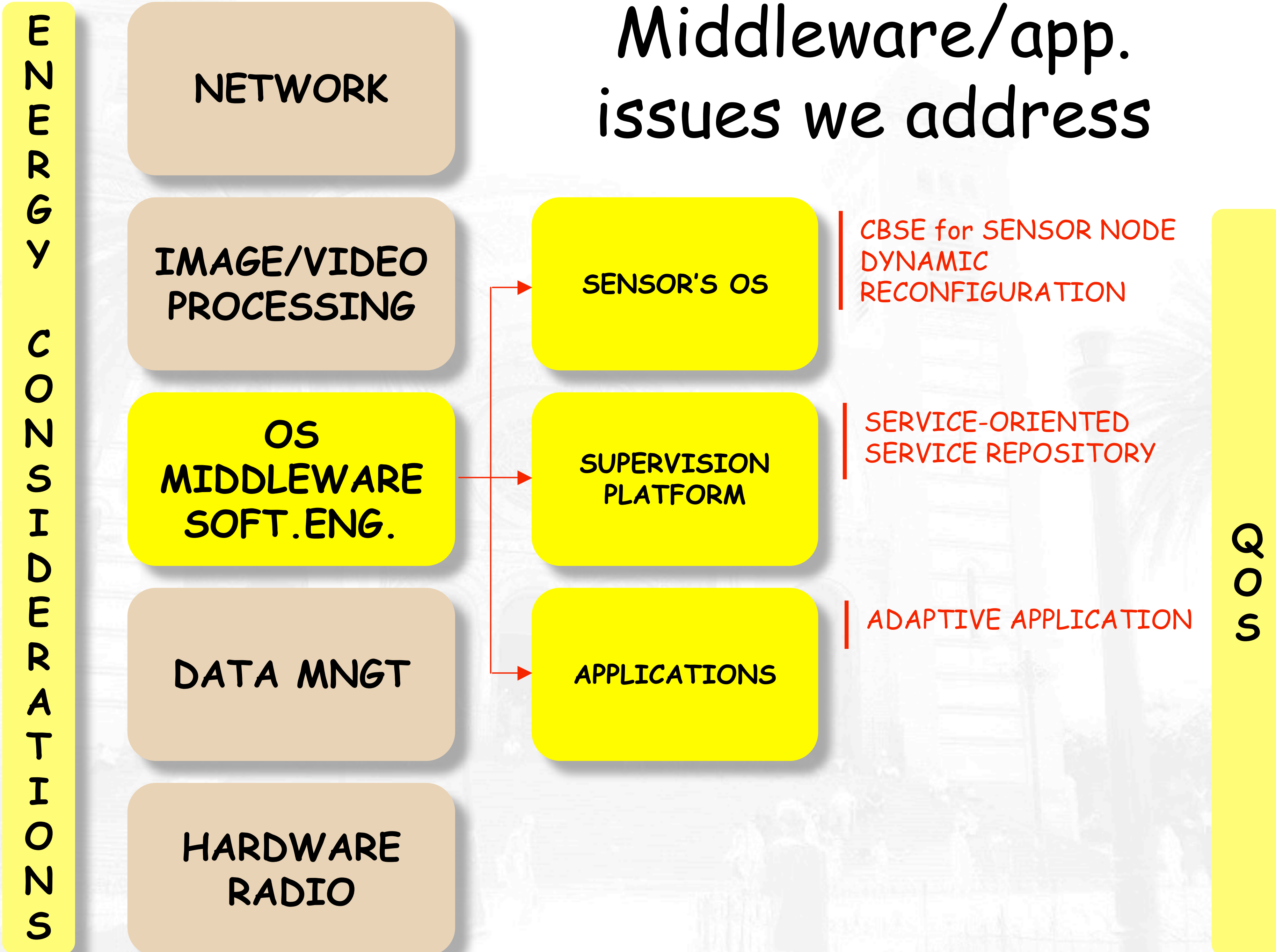
Surveillance as a service: Accountability



Research issues in WSN



Middleware/app. issues we address



Network issues we address

ENERGY CONSIDERATIONS

NETWORK

IMAGE/VIDEO PROCESSING

OS MIDDLEWARE SOFT. ENG.

DATA MNGT

HARDWARE RADIO

ORGANIZATION OVERLAYS

VIDEO COVERAGE SELECTION & WAKE-UP MECHANISM

TRANSPORT

LOAD-REPARTITION CONGESTION CONTROL

ROUTING

MULTI-PATHS ROUTING

MAC RESOURCES ALLOCATION

QOS

Application's criticality

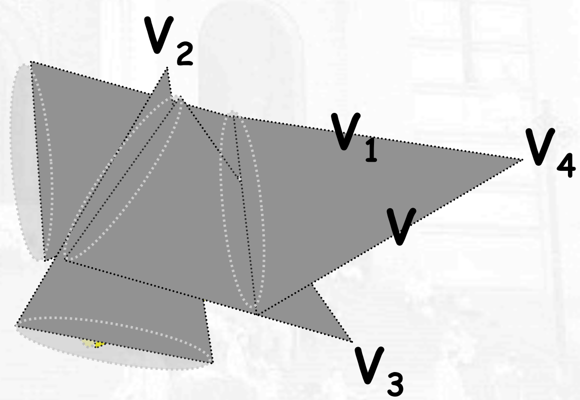
- All surveillance applications may not have the same criticality level, $r^0 \in [0,1]$
  - Environmental, security, healthcare,...
- Capture speed should decrease when r^0 decreases
- Sensor nodes could be initialized with a given r^0 prior to deployment

How to meet 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

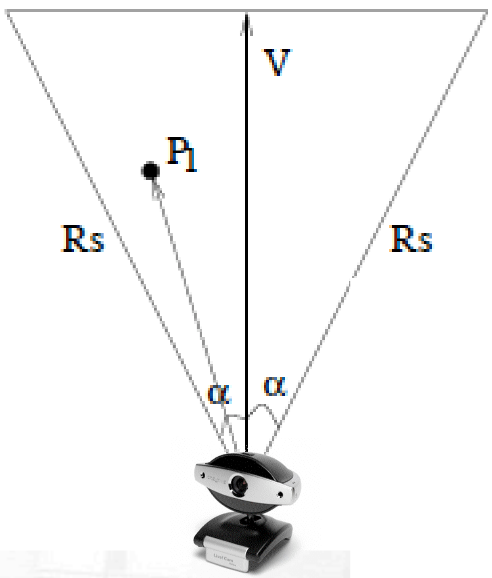
Node's cover set

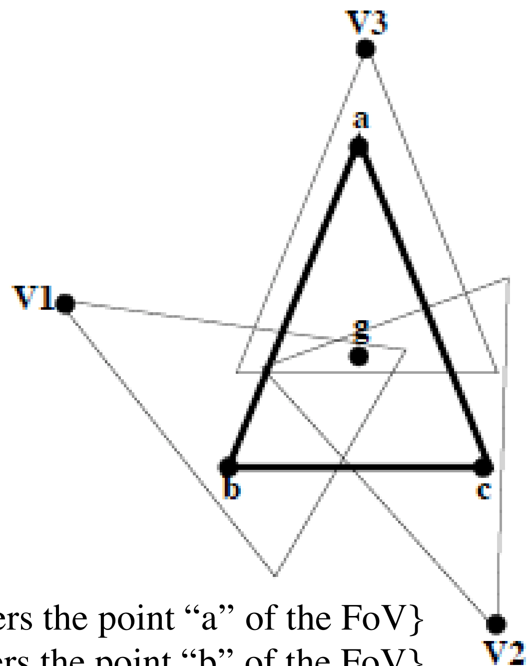
- Each node v has a Field of View, FoV_v
- $Co_i(v)$ = set of nodes v' such as $\bigcup_{v' \in Co_i(v)} FoV_{v'}$ covers FoV_v
- $Co(v)$= set of $Co_i(v)$



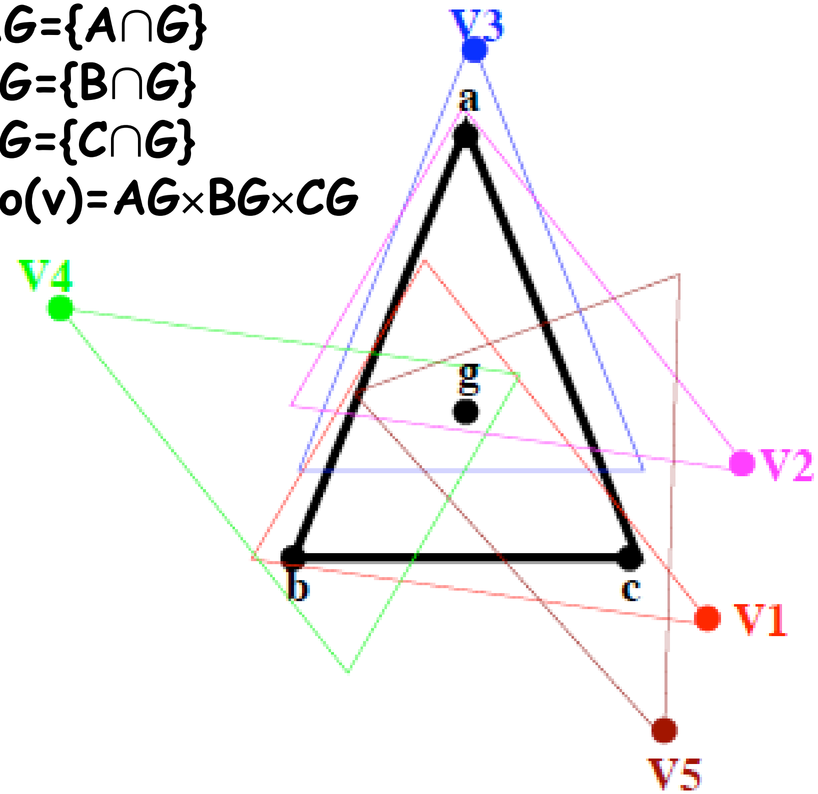
$Co(v)=\{V_1,V_2,V_3,V_4\}$

Finding v's cover set





$AG = \{A \cap G\}$
$BG = \{B \cap G\}$
$CG = \{C \cap G\}$
$Co(v) = AG \times BG \times CG$

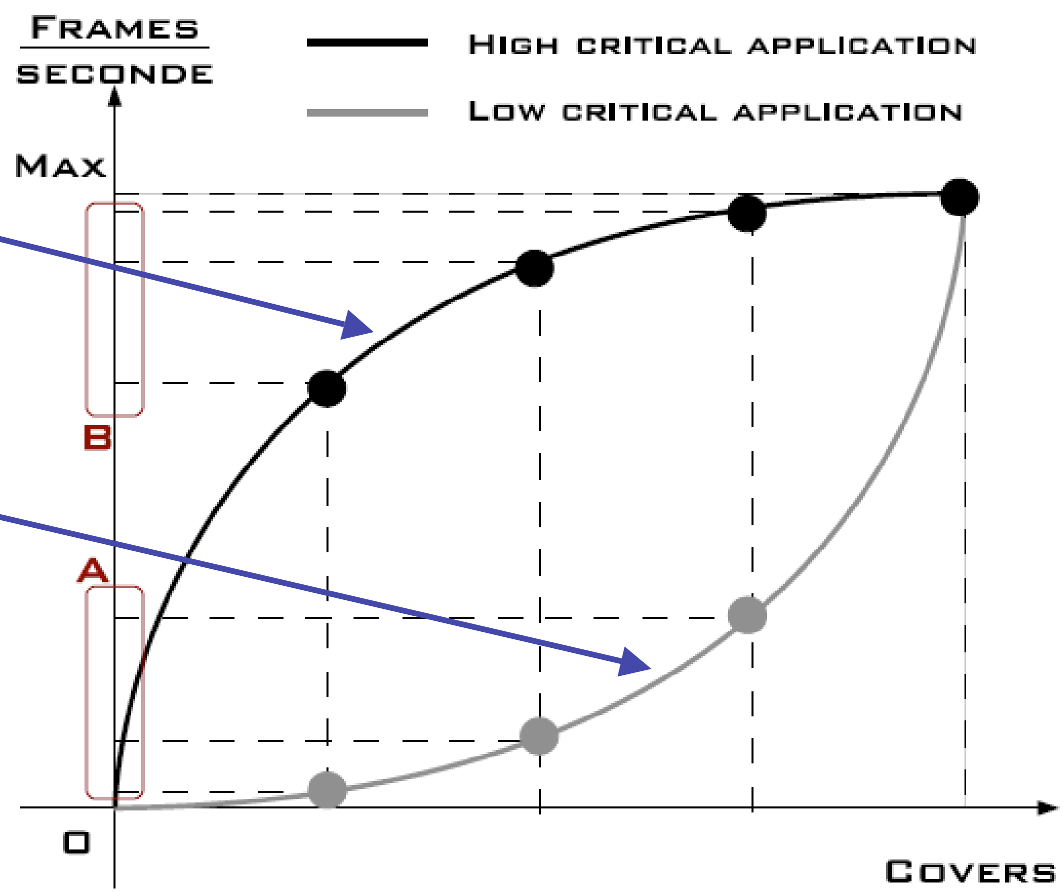


A = {v ∈ N(V) : v covers the point "a" of the FoV}
B = {v ∈ N(V) : v covers the point "b" of the FoV}
C = {v ∈ N(V) : v covers the point "c" of the FoV}
G = {v ∈ N(V) : v covers the point "g" of the FoV}

Co(V)= {
{V },
{V 2, V 1},
{V 3, V 1},
{V 2, V 4, V 5},
{V 3, V 4, V 5}}

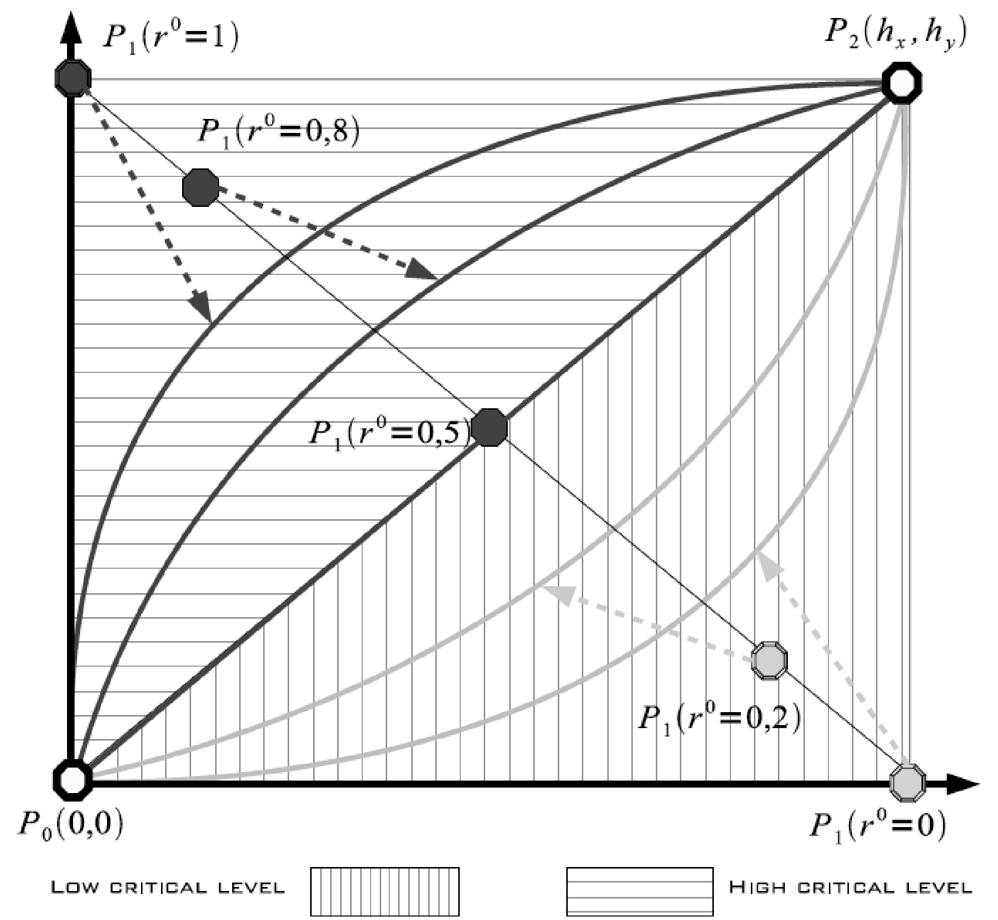
Criticality model (1)

- 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



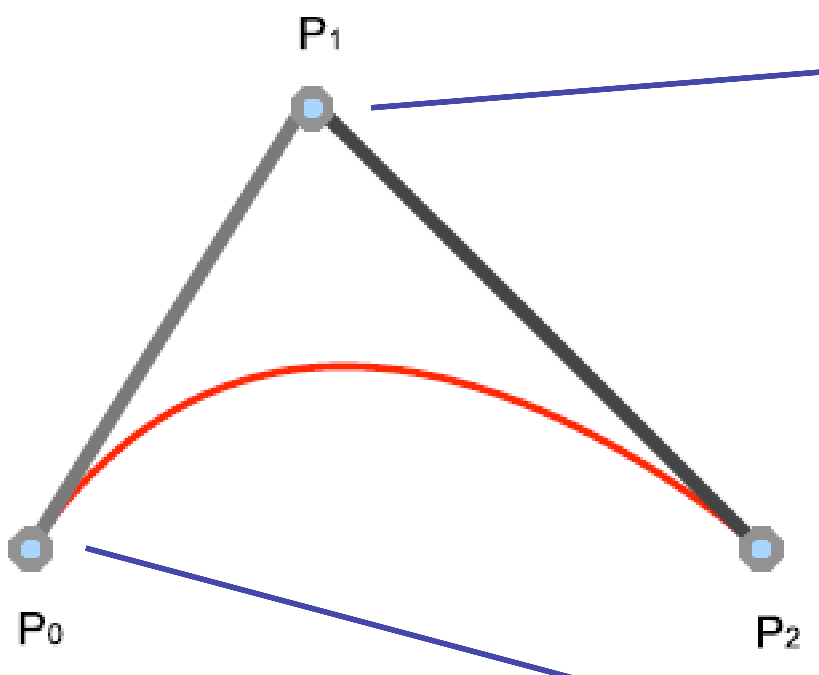
Criticality model (2)

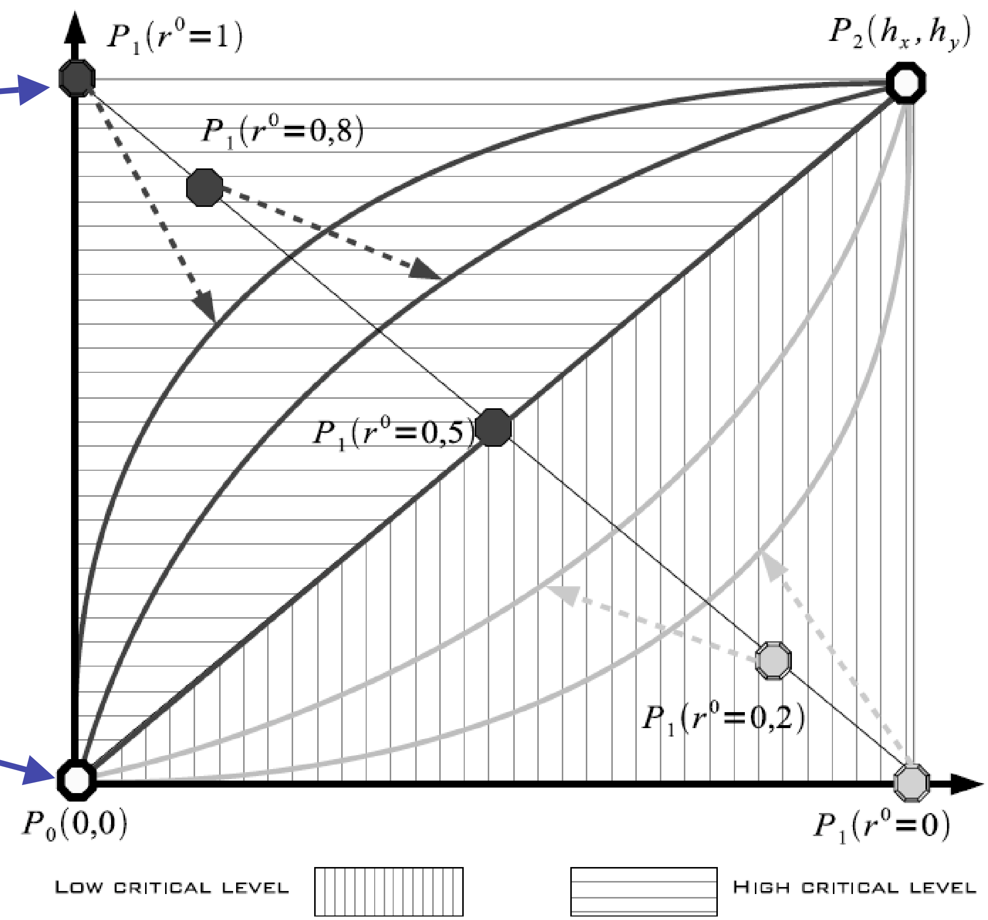
- r^0 can vary in [0,1]
- BehaVior functions (BV) defines the capture speed according to r^0
- $r^0 < 0.5$
  - Concave shape BV
- $r^0 > 0.5$
  - Convex shape BV
- We propose to use Bézier curves to model BV functions



BehaVior function

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





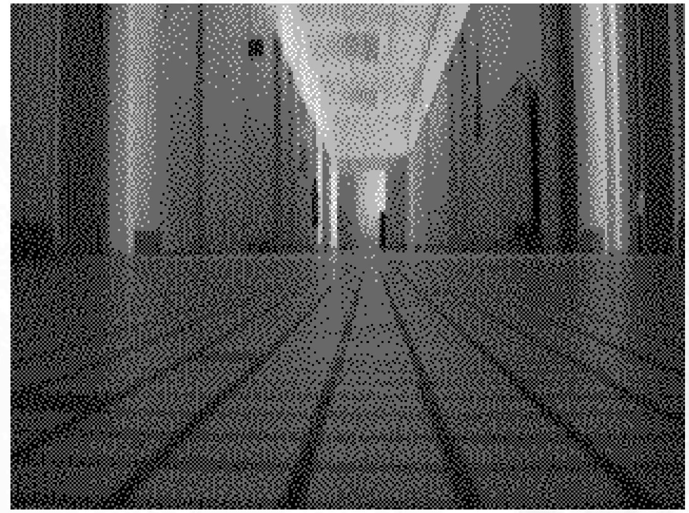
Some typical capture speed

- Maximum capture speed is 6fps
- Nodes with size of cover set greater than 6 capture at the maximum speed

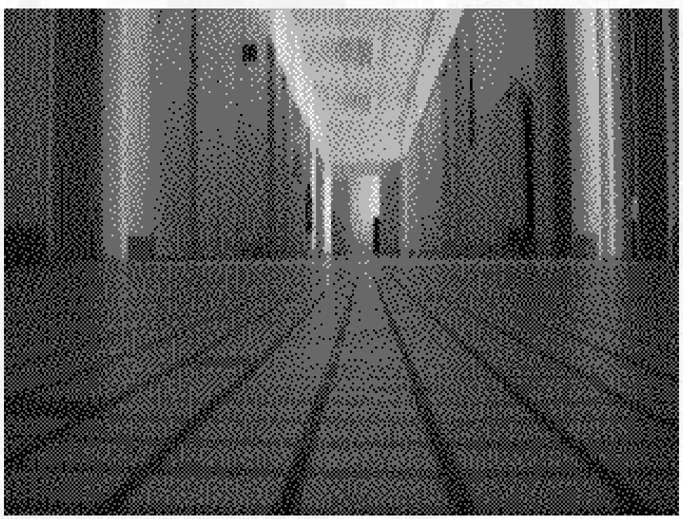
r^0 \ $\lvert Co(v) \rvert$	1	2	3	4	5	6
0.0	0.05	0.20	0.51	1.07	2.10	6.00
0.2	0.30	0.73	1.34	2.20	3.52	6.00
0.5	1.00	2.00	3.00	4.00	5.00	6.00
0.8	2.48	3.80	4.66	5.27	5.70	6.00
1.0	3.90	4.93	5.49	5.80	5.95	6.00

320x200, 30 fps, 256 gray scale
15Mbps raw

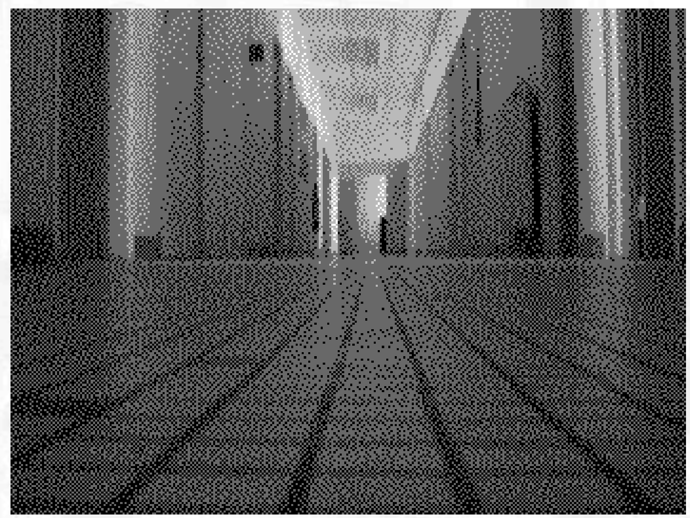
5 fps, 4 gray scale, 640kbps raw



2 fps, 4 gray scale, 256kbps raw



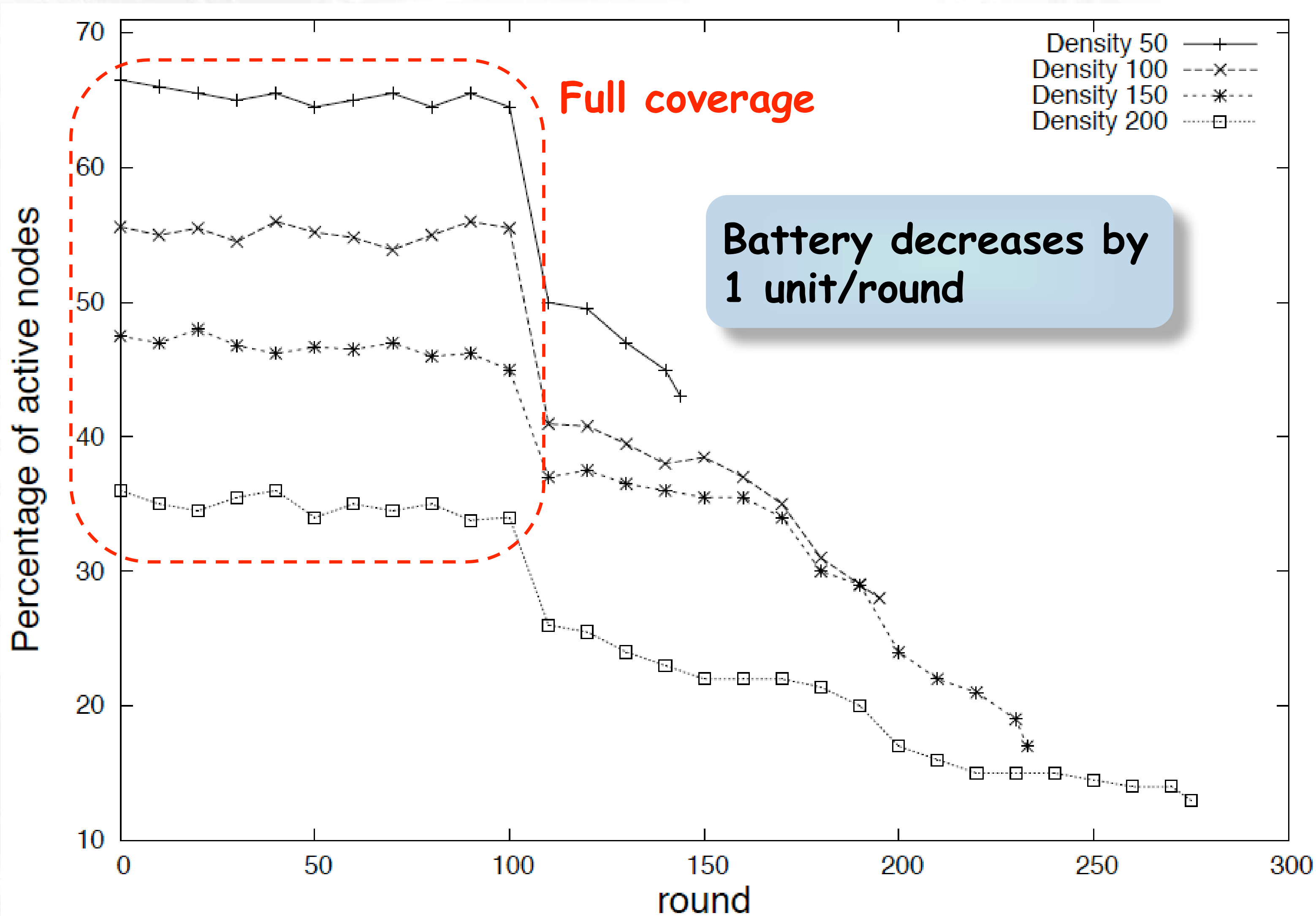
1 fps, 4 gray scale, 128kbps raw



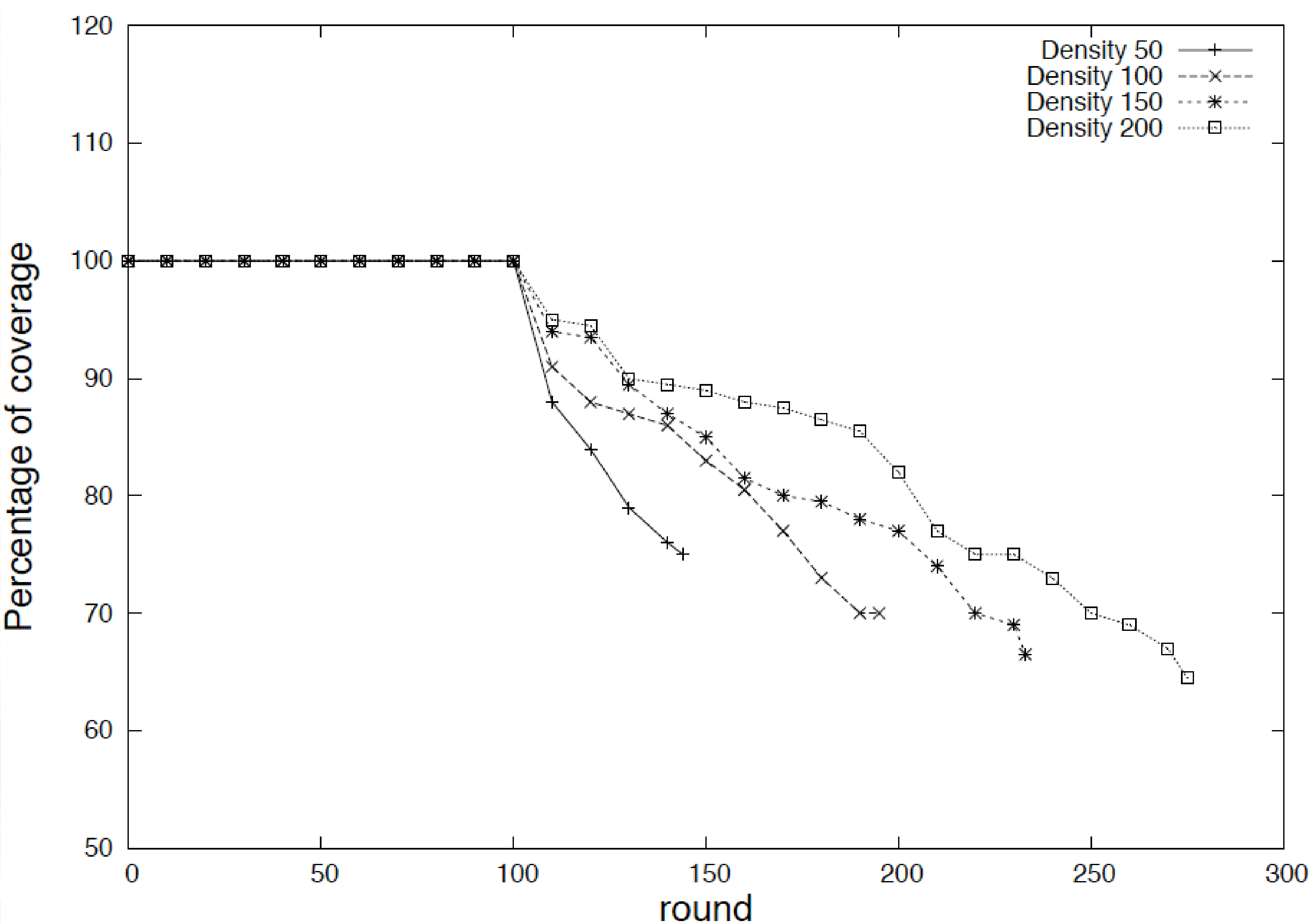
Simulation settings

- OMNET++ simulation model
- Video nodes have communication range of 30m and video sensing range of 25m, FoV is a sector of 60°
- Battery has 100 units
- Full coverage is defined as the region initially covered when all nodes are active

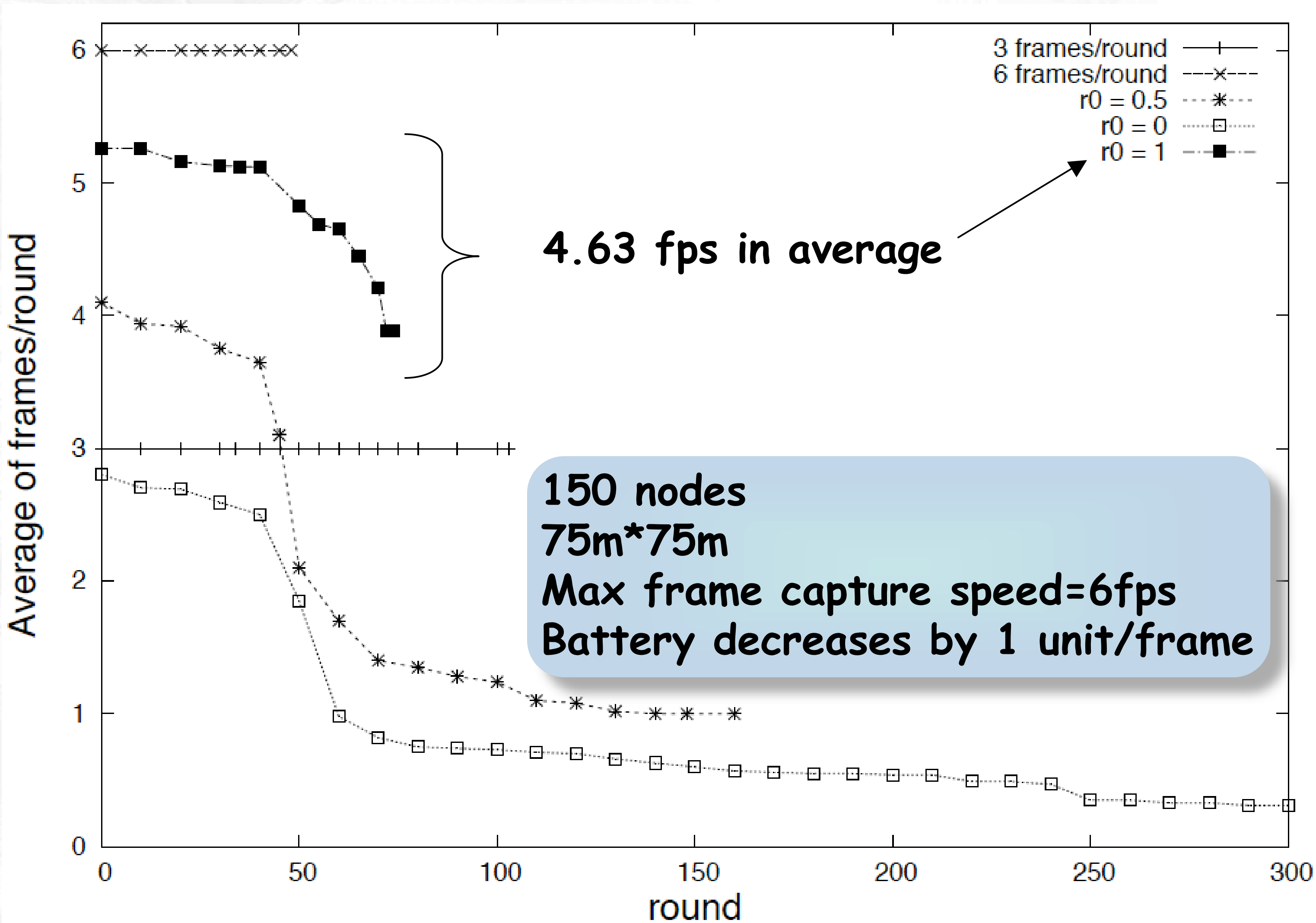
Percentage of active nodes



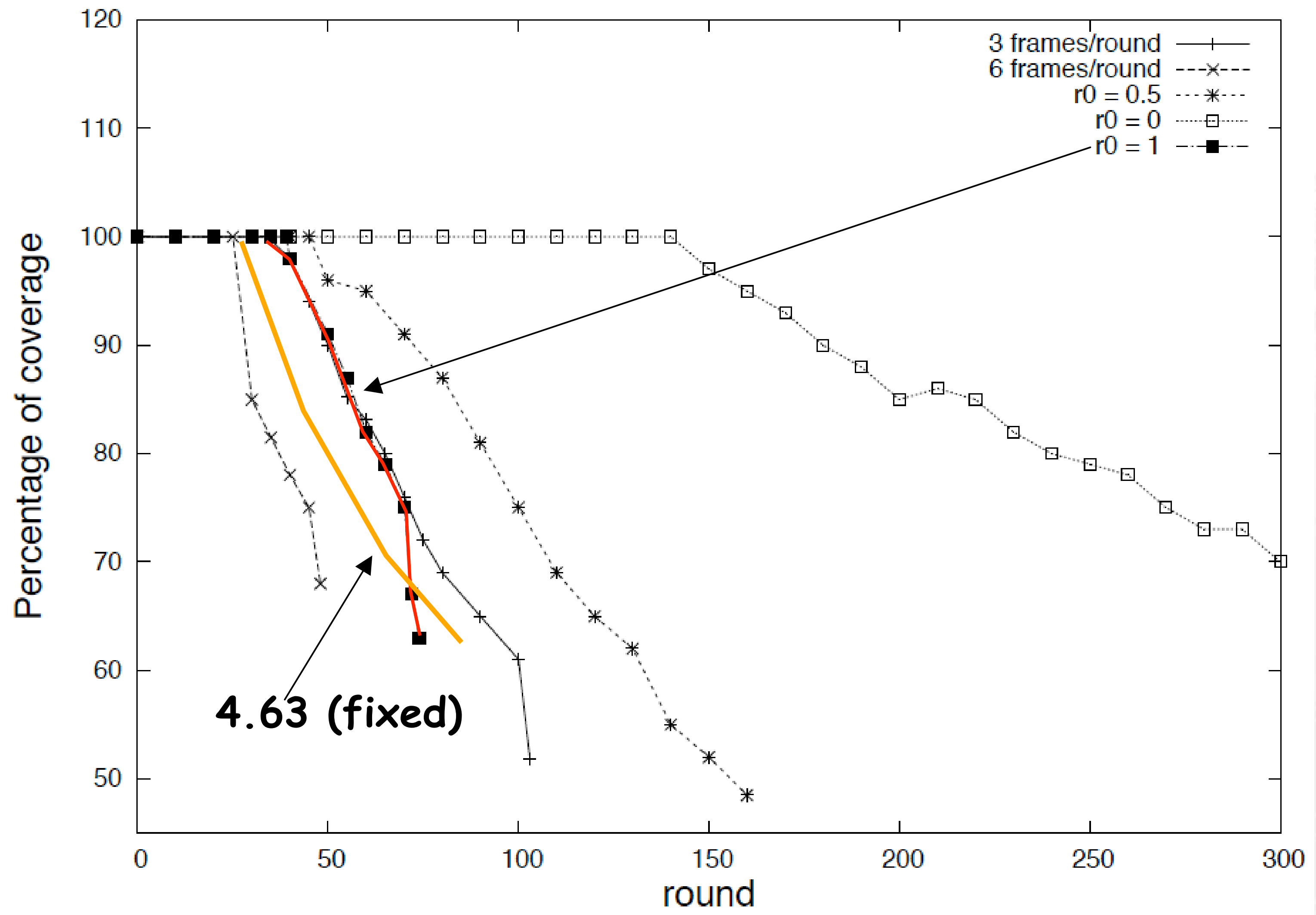
Percentage of coverage



Average capture speed



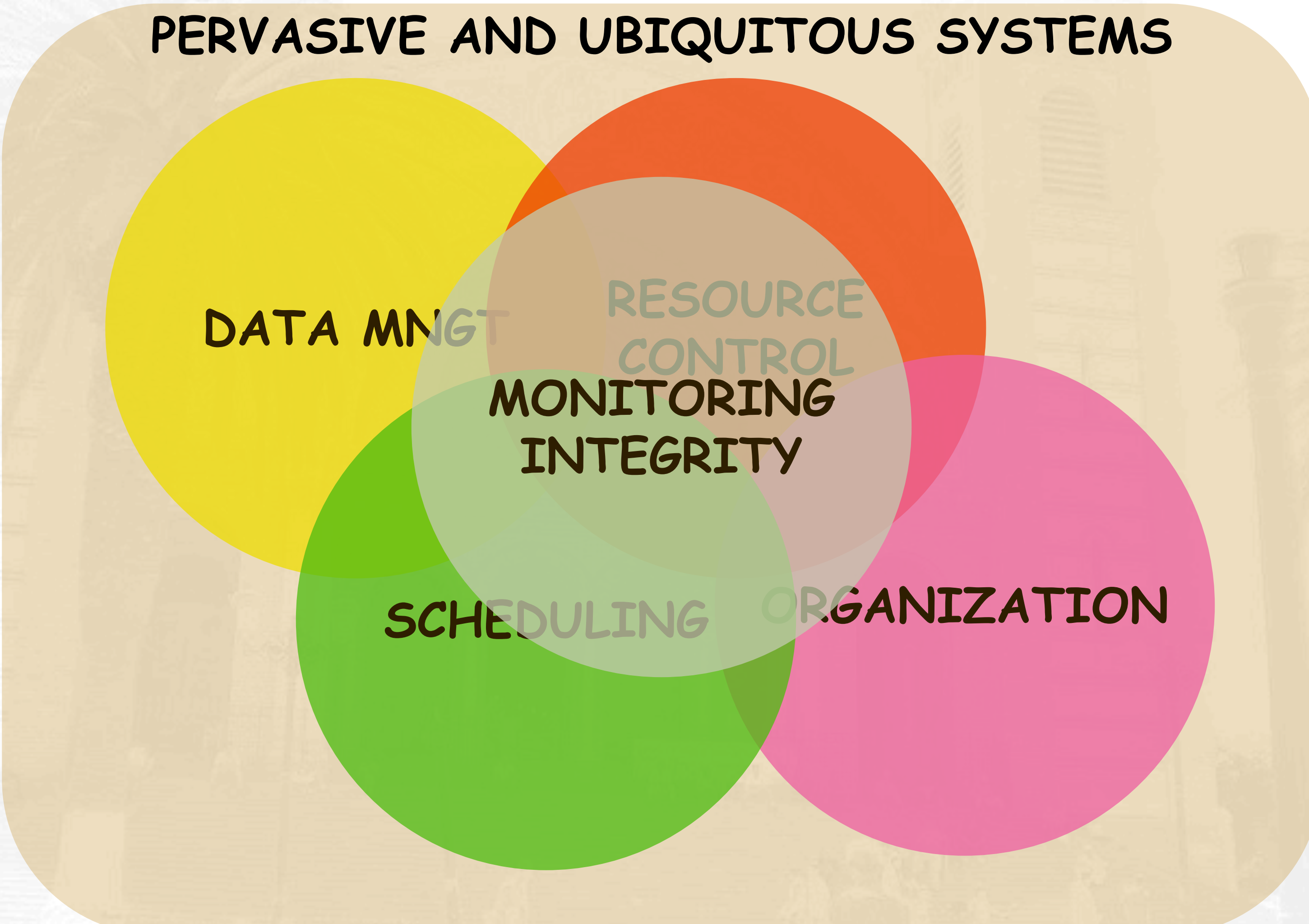
Fixed vs adaptive



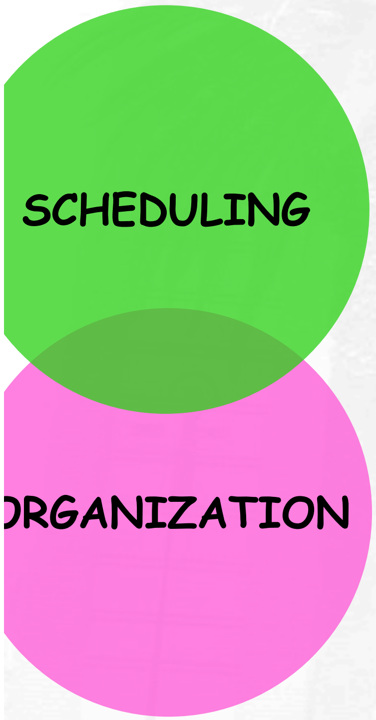
Conclusions

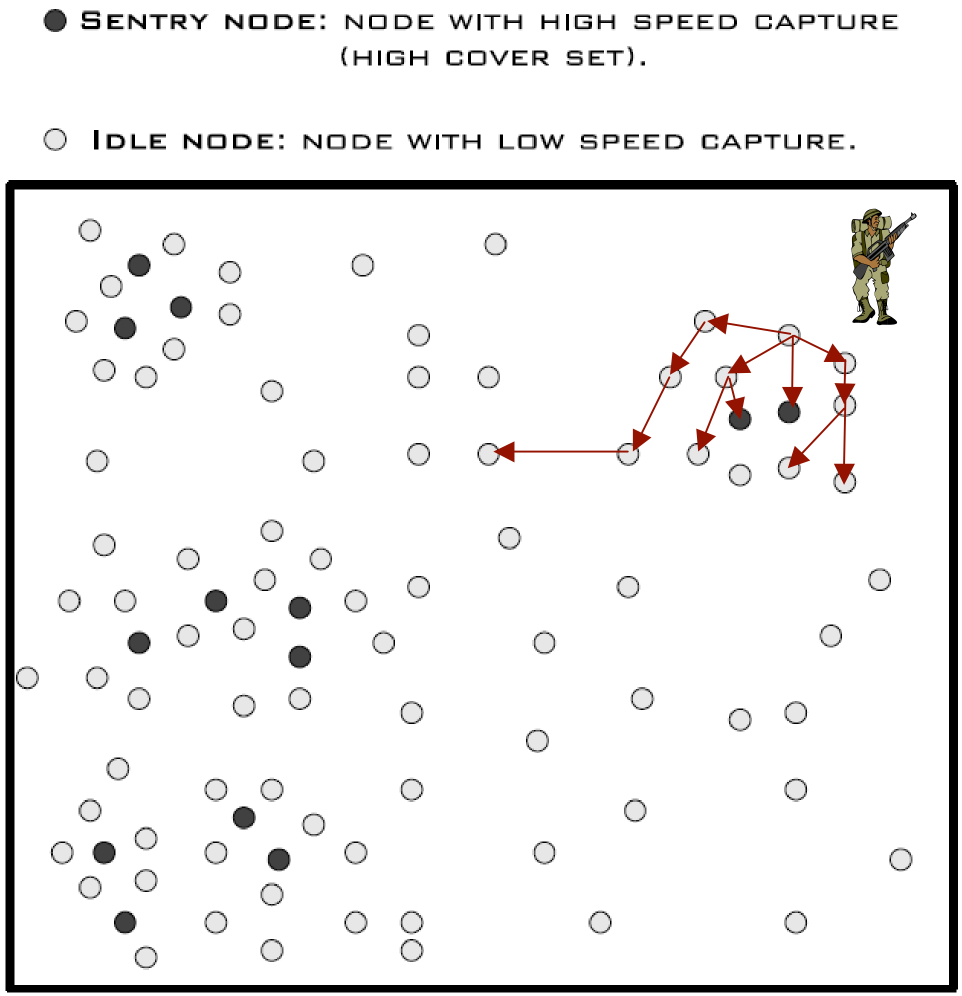
- Surveillance applications have a high level of criticity which make accountability important
- Criticality model with adaptive scheduling of nodes
- Optimize the resource usage by dynamically adjusting the provided service level
- Extension for risk-based scheduling in intrusion detection systems

Research directions

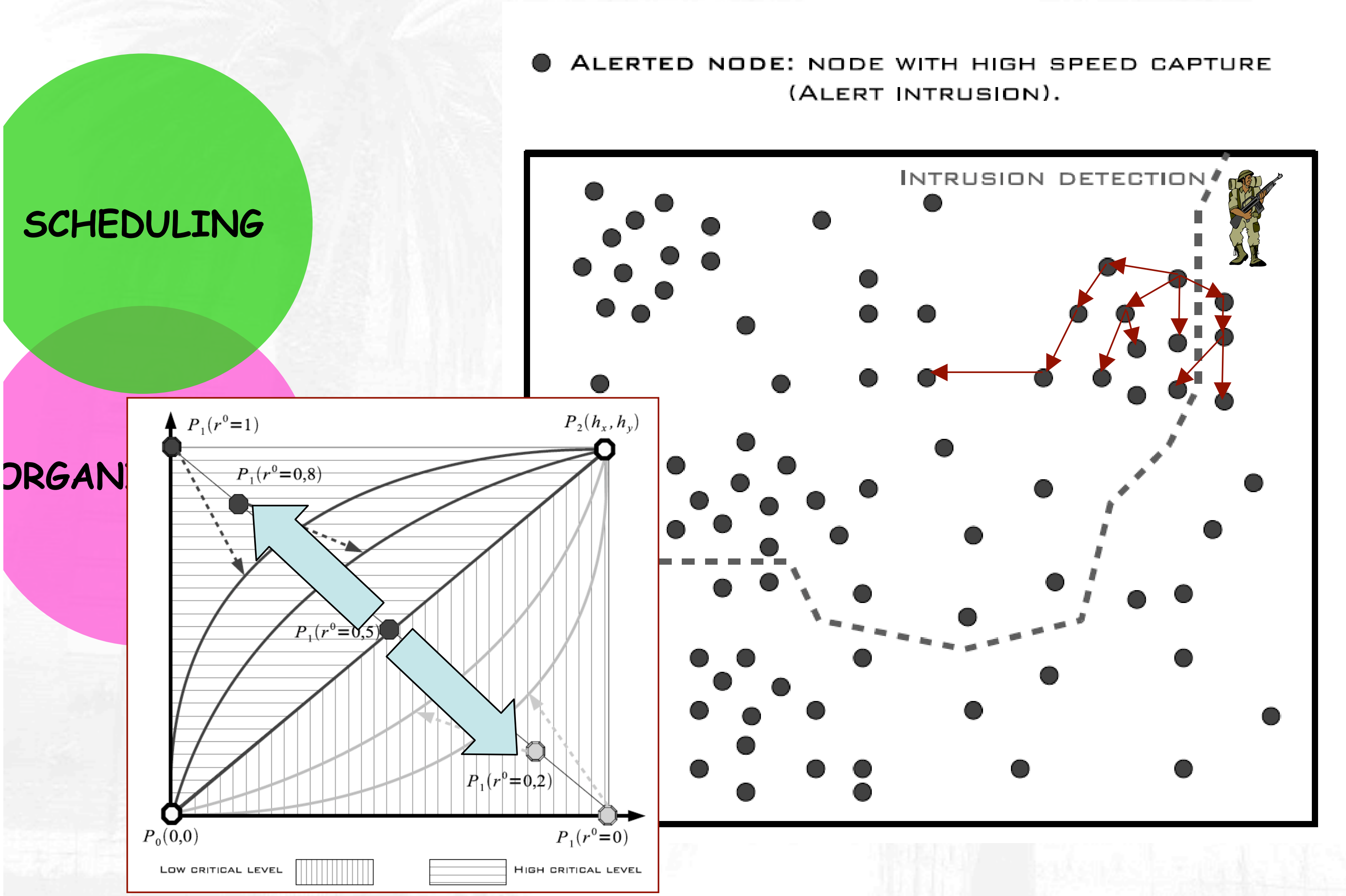


Controlled propagation (1)

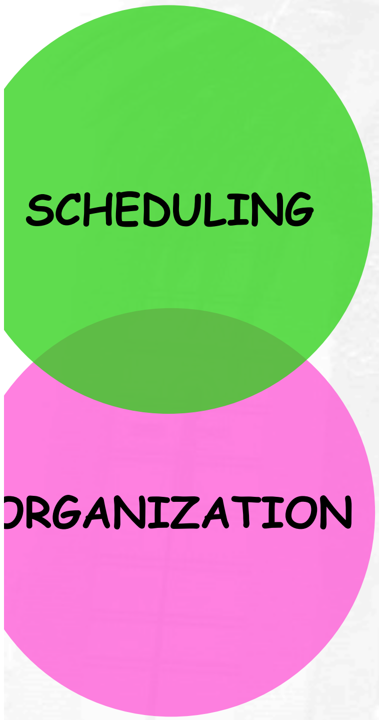




Controlled propagation (2)



Controlled propagation (3)



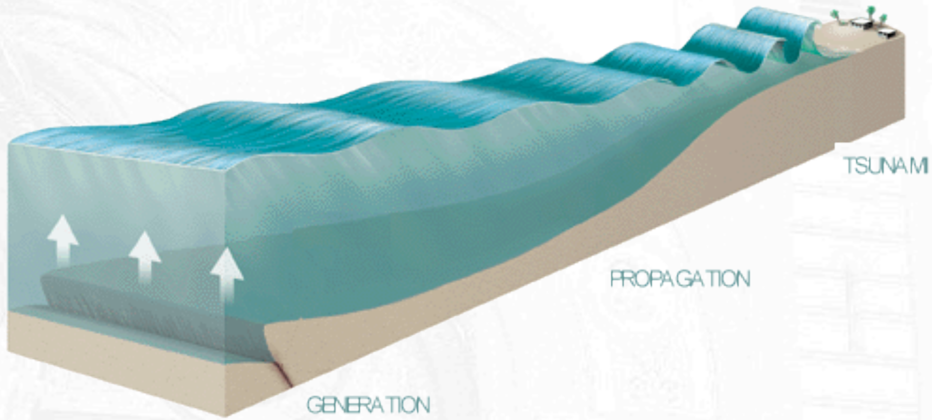
- Not a simple propagation or broadcast algorithm
  - Not all nodes need to be at the maximum (same) alert level
  - Which nodes should be more than others?
- Borrow propagation model from other disciplines
  - Epidemic propagation, percolation, wave propagation,…
  - According to the model, map the parameter of a surveillance system to the model's parameters

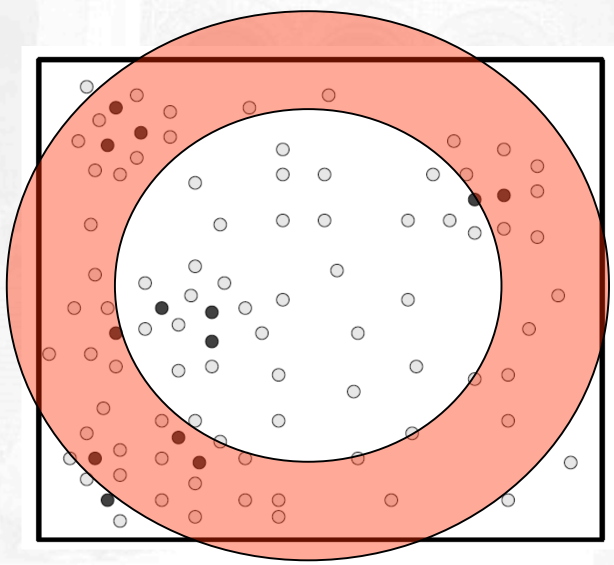
Controlled propagation (4)

ex: tsunami generation

SCHEDULING

ORGANIZATION



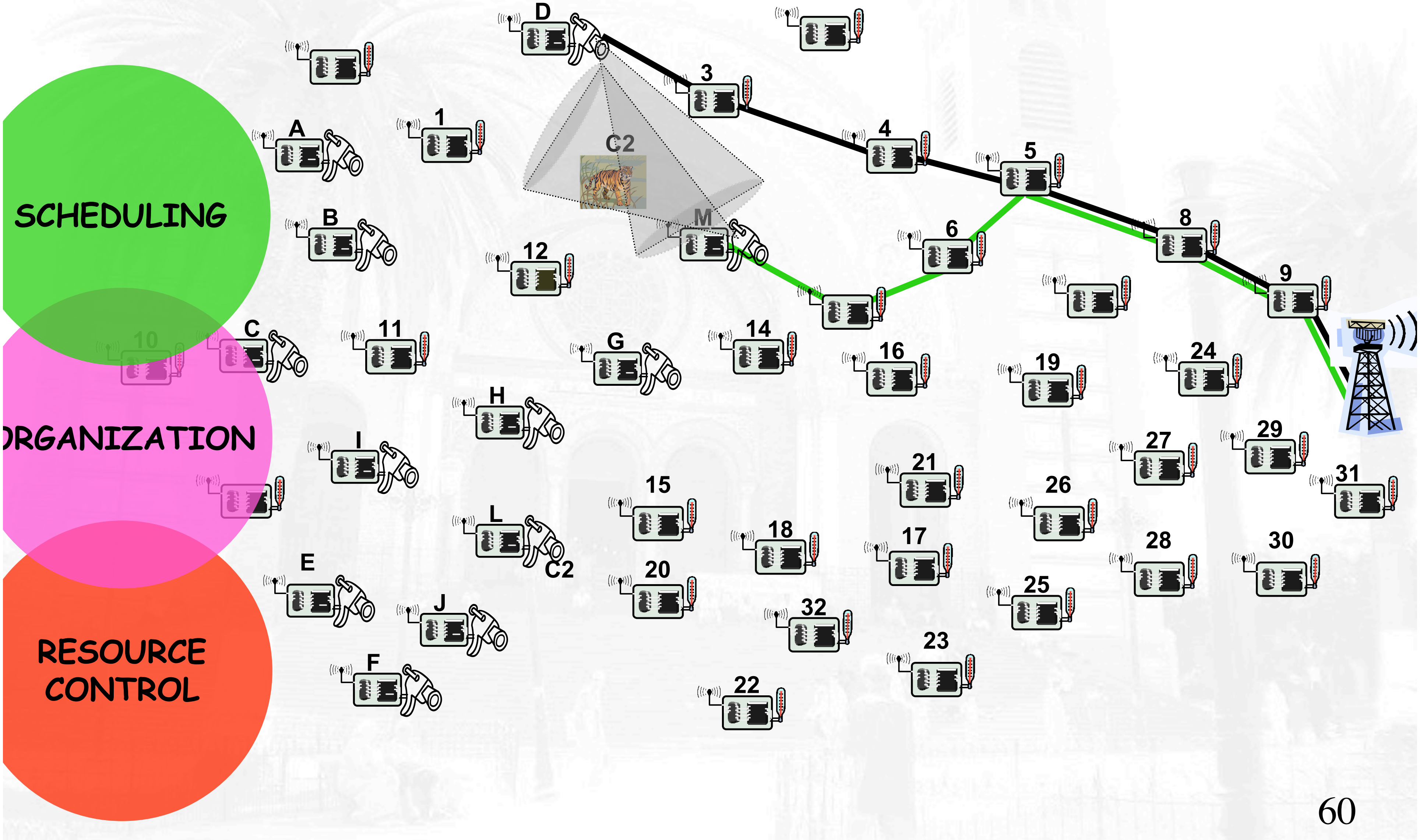


sensor nodes near the border may need to be « alerted » than others, they could have an amplification factor greater than those near the centre

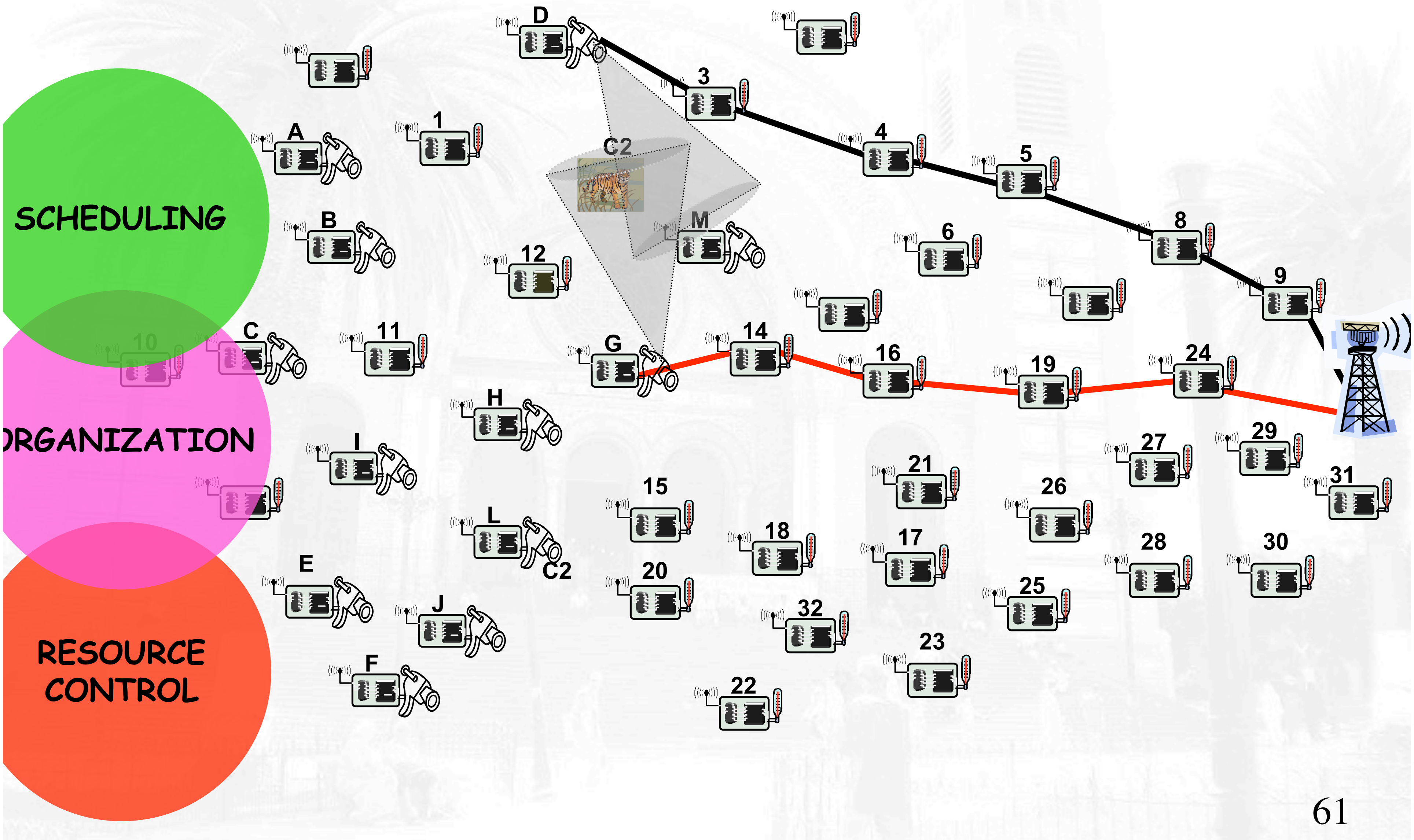
Congestion control (1)

- Lot's of video nodes=lot's of trafic
- High probability of bottleneck, lot's of packet drop, no useful data back to user!
- Scheduling is tighly linked to resource control to be efficient
- Scheduling is then not only find these nodes that « see » the event, but also how to select a subset of those nodes that minimizes congestion

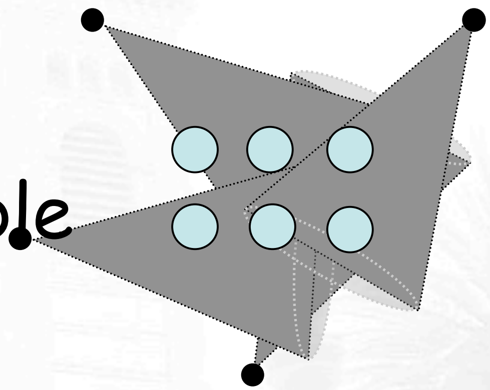
Congestion control (2)



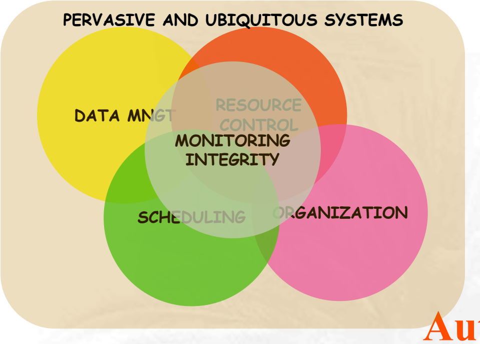
Congestion control (3)



Scheduling cover-set

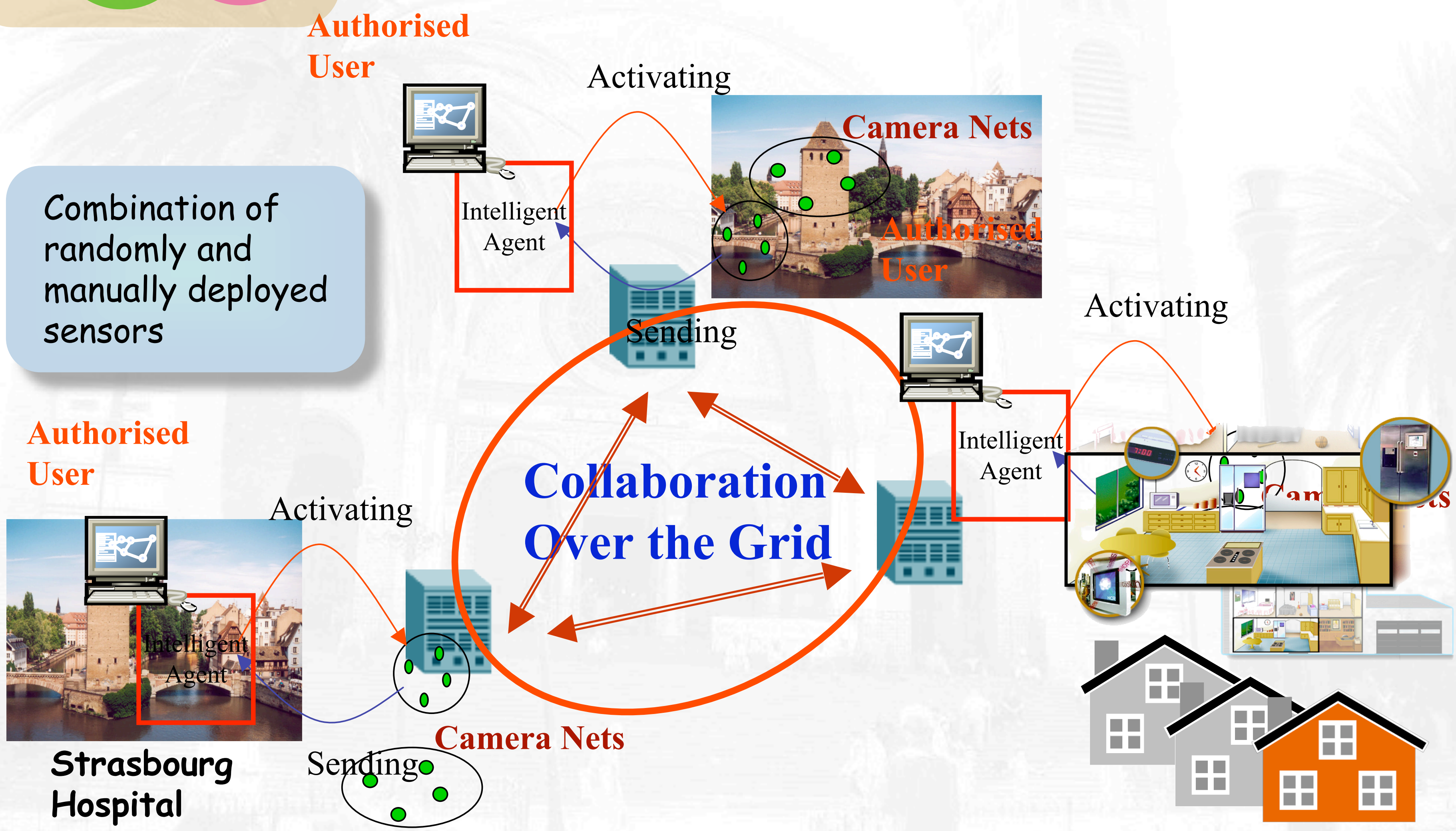


- On intrusion, it is desirable to use more camera
  - To circumvent occlusions
  - To help for disambiguation
- It is not necessary that all activated camera capture at a same speed (probably high speed)
  - How to distribute the target frame capture speed (i.e. 6fps) on a set of camera to obtain a so-called « equivalent capture speed »?



Towards large-scale pervasive environments

Combination of randomly and manually deployed sensors



More generally…

- Use cooperation (knowledge sharing) to enhance the basic services
- Define what is « cooperation » in sensor networks for surveillance (specific case of distributed systems)
- Find what are the outcome of such cooperation
- Find how cooperation could be realized at a given layer