Dynamic risk-based scheduling and mobility of sensors for surveillance system

ROSIN Workshop
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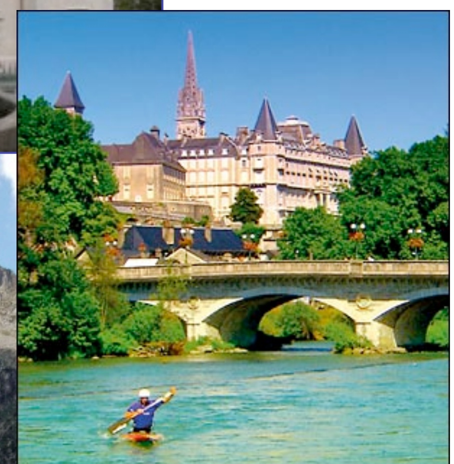
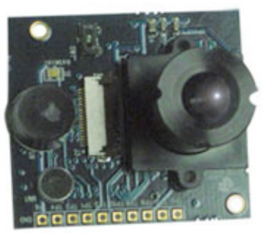
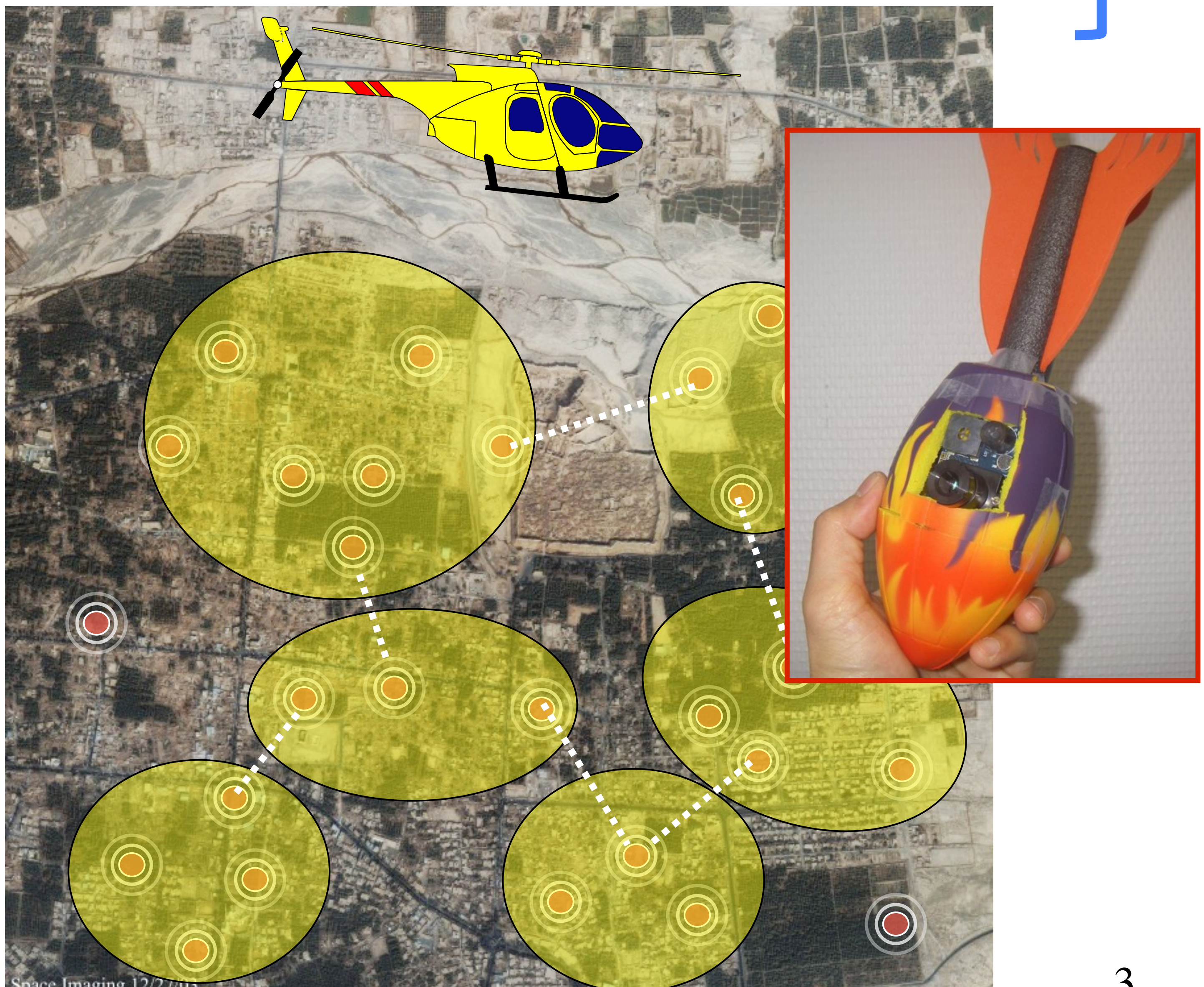


Wireless Video Sensors (1)

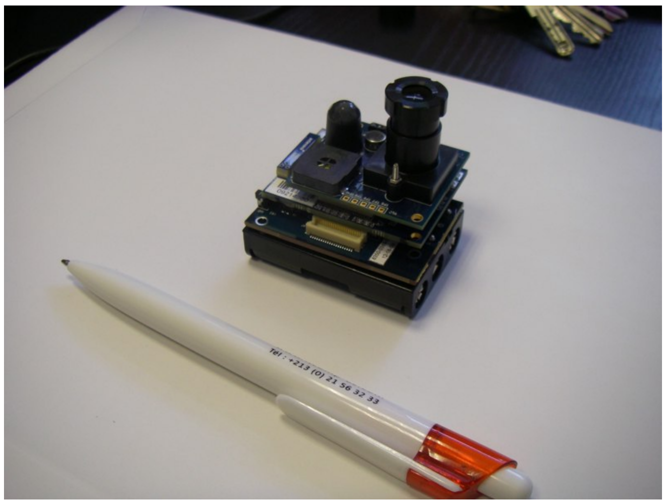
Imote2

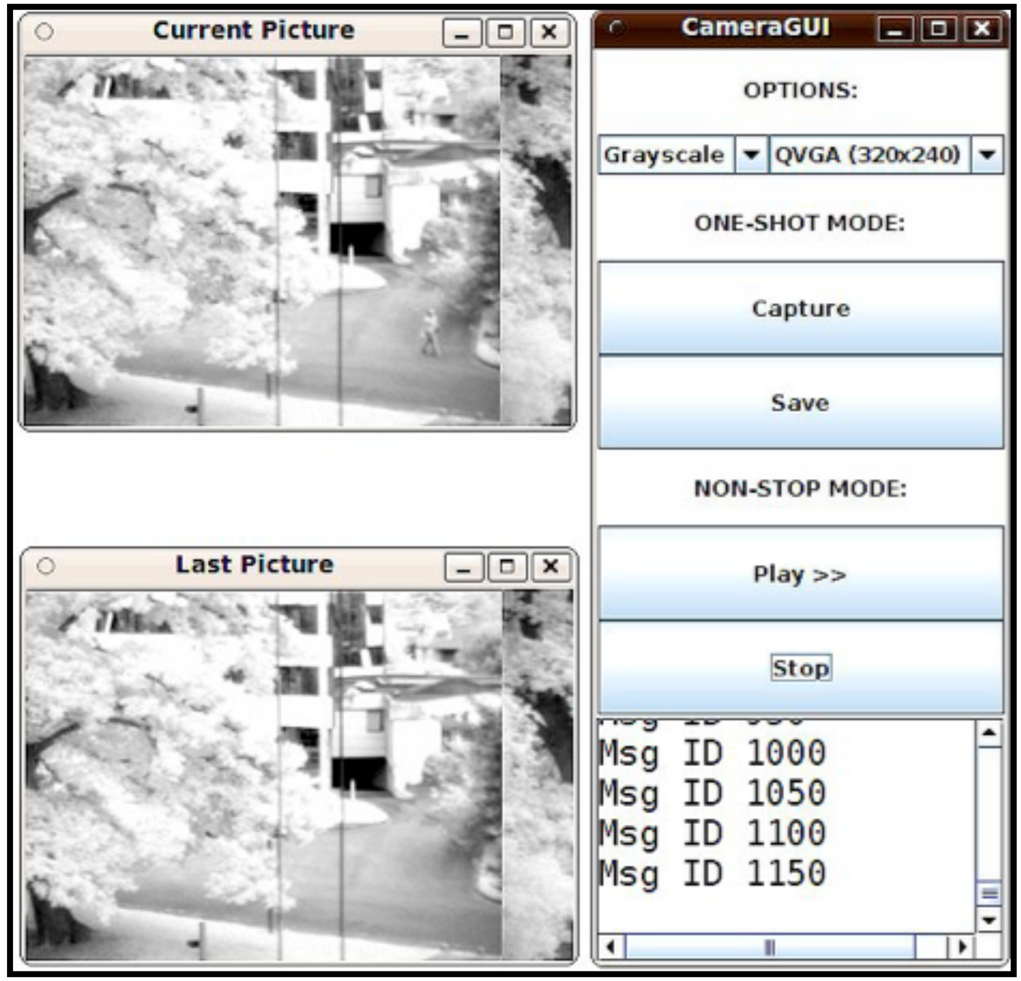


Multimedia board



Wireless Video Sensors (2)



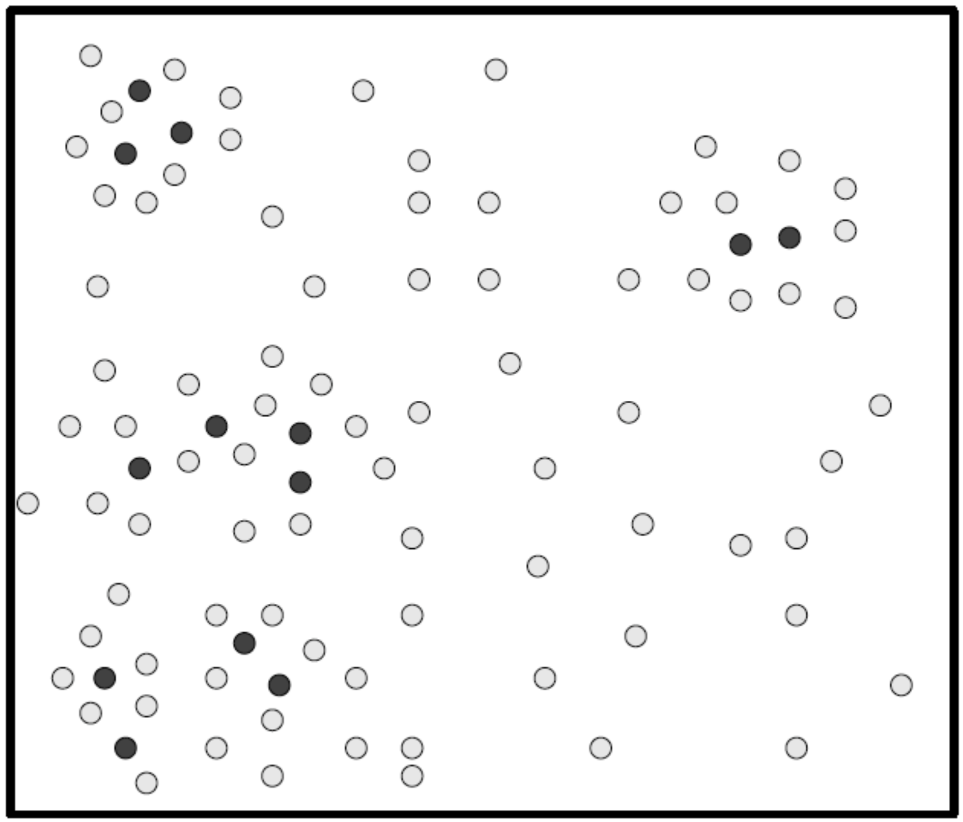


Surveillance scenario (1)

- 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

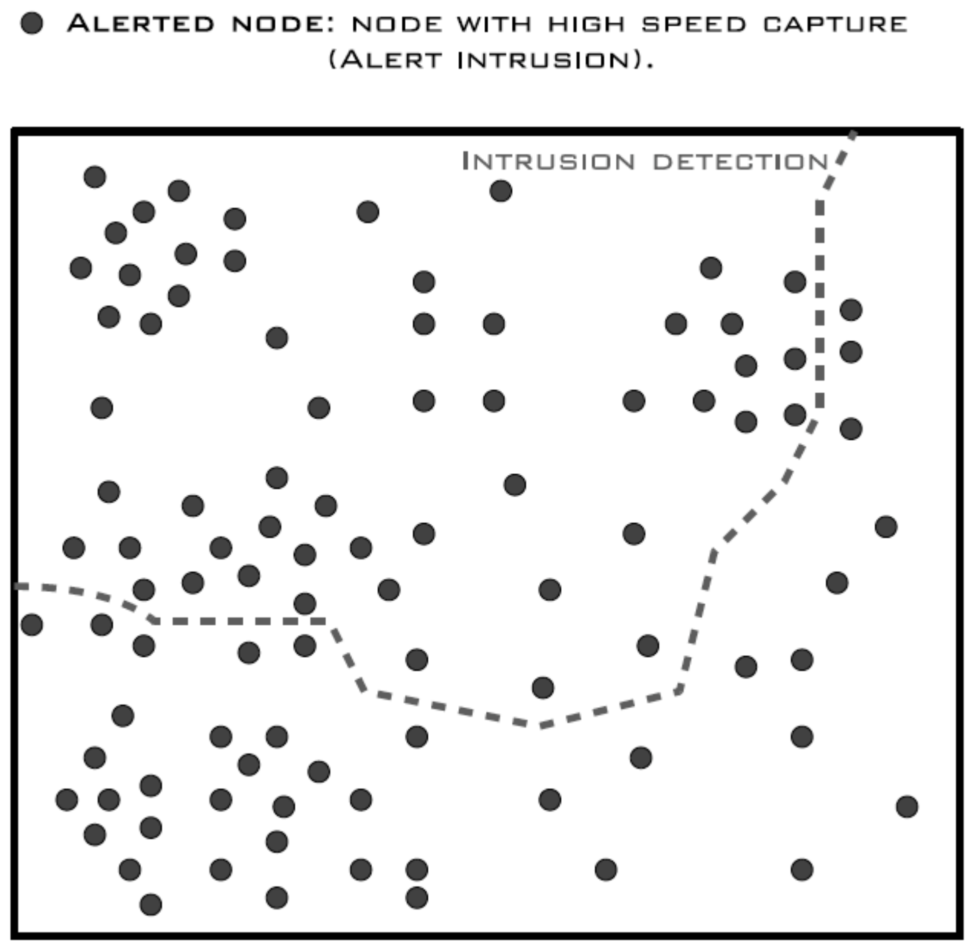
● Sentry node: node with high speed capture (high cover set).

○ Idle node: node with low speed capture.

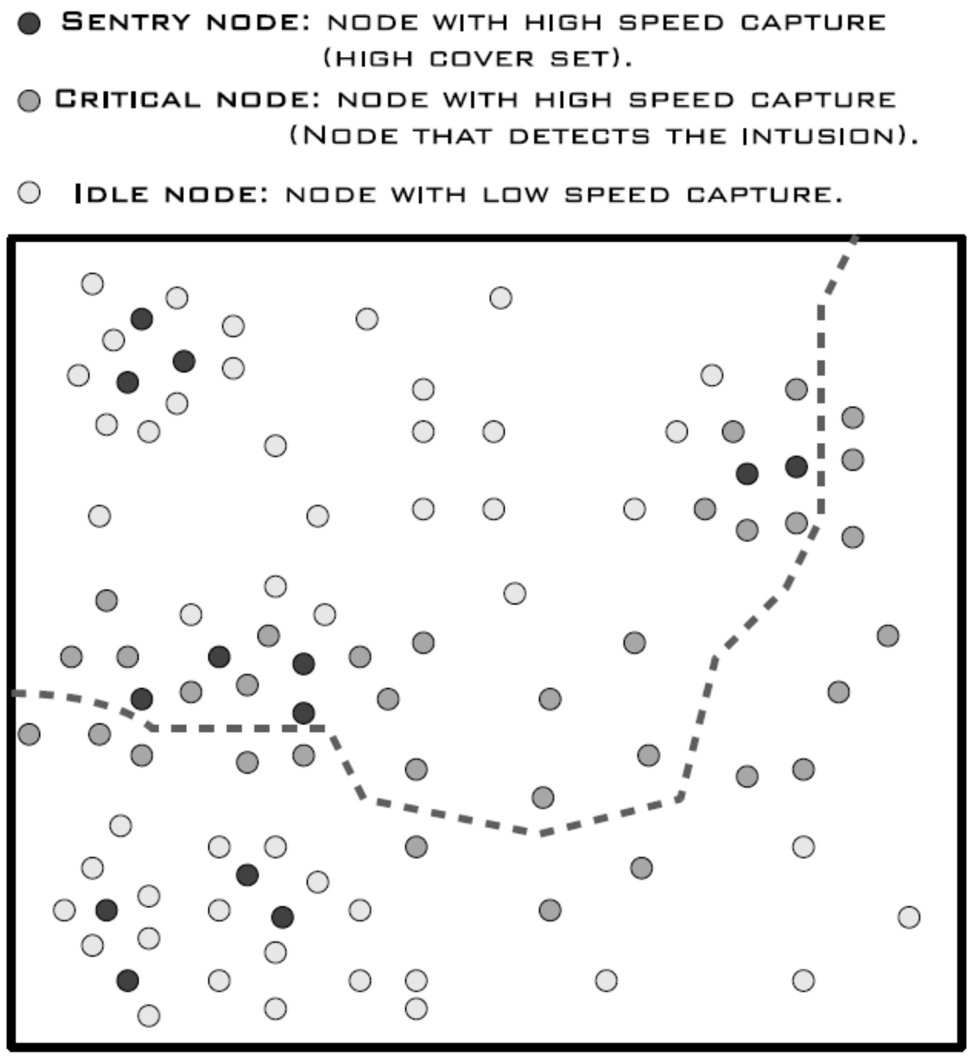


Surveillance scenario (2)

- 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



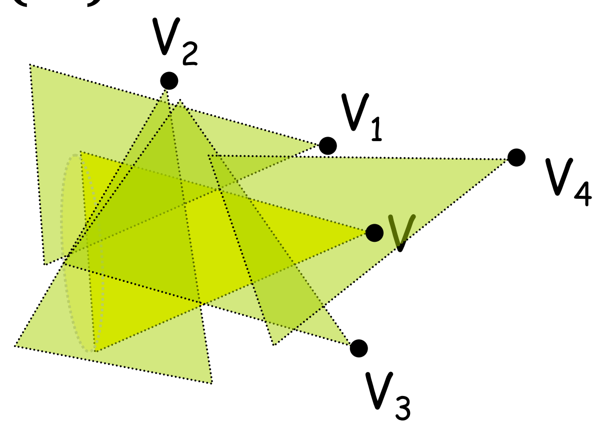
Surveillance scenario (3)



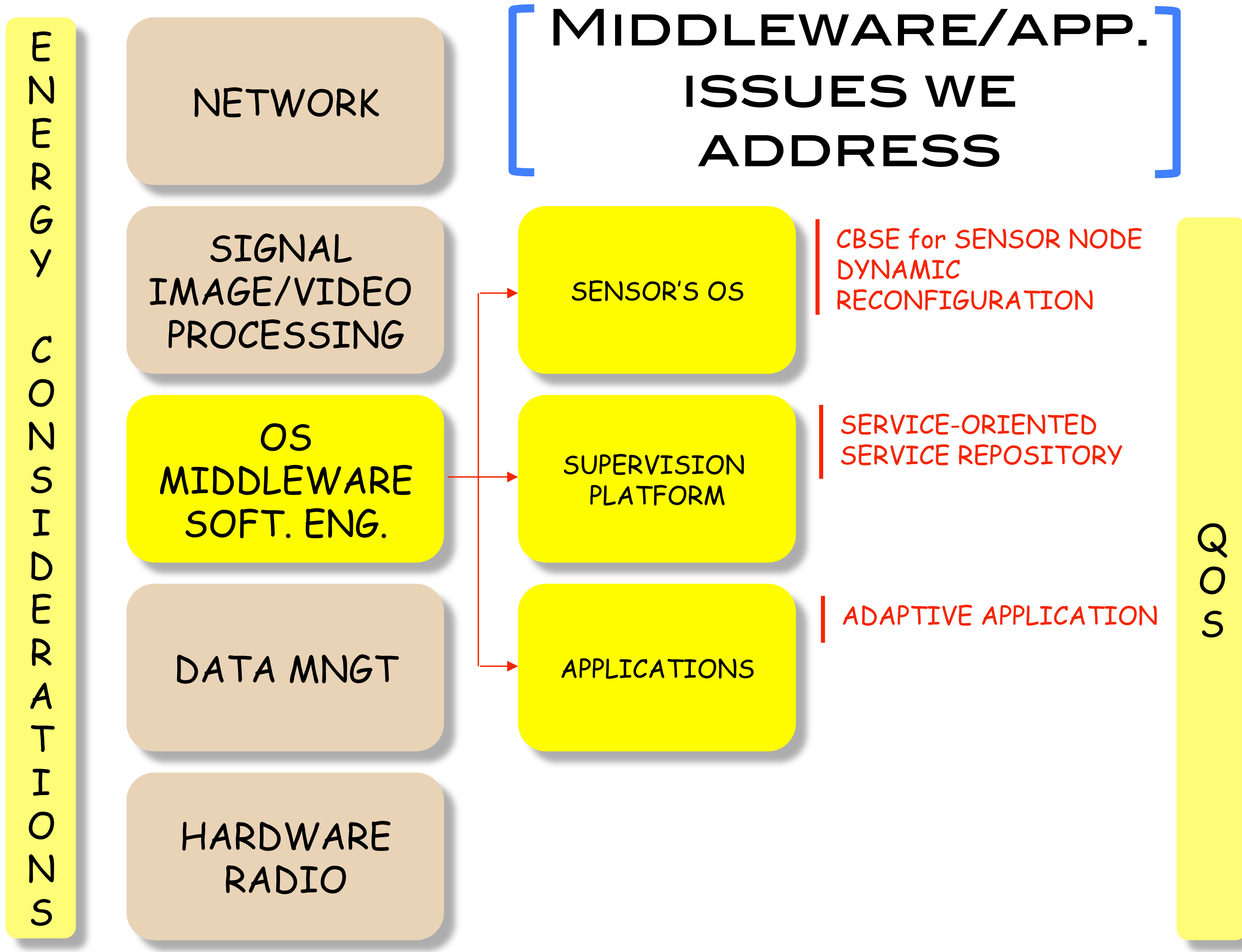
- Network should go back to *hibernate mode*
- Nodes on the intrusion path must keep a high capture speed
- Sentry nodes with higher capture speed to quickly detect intrusions

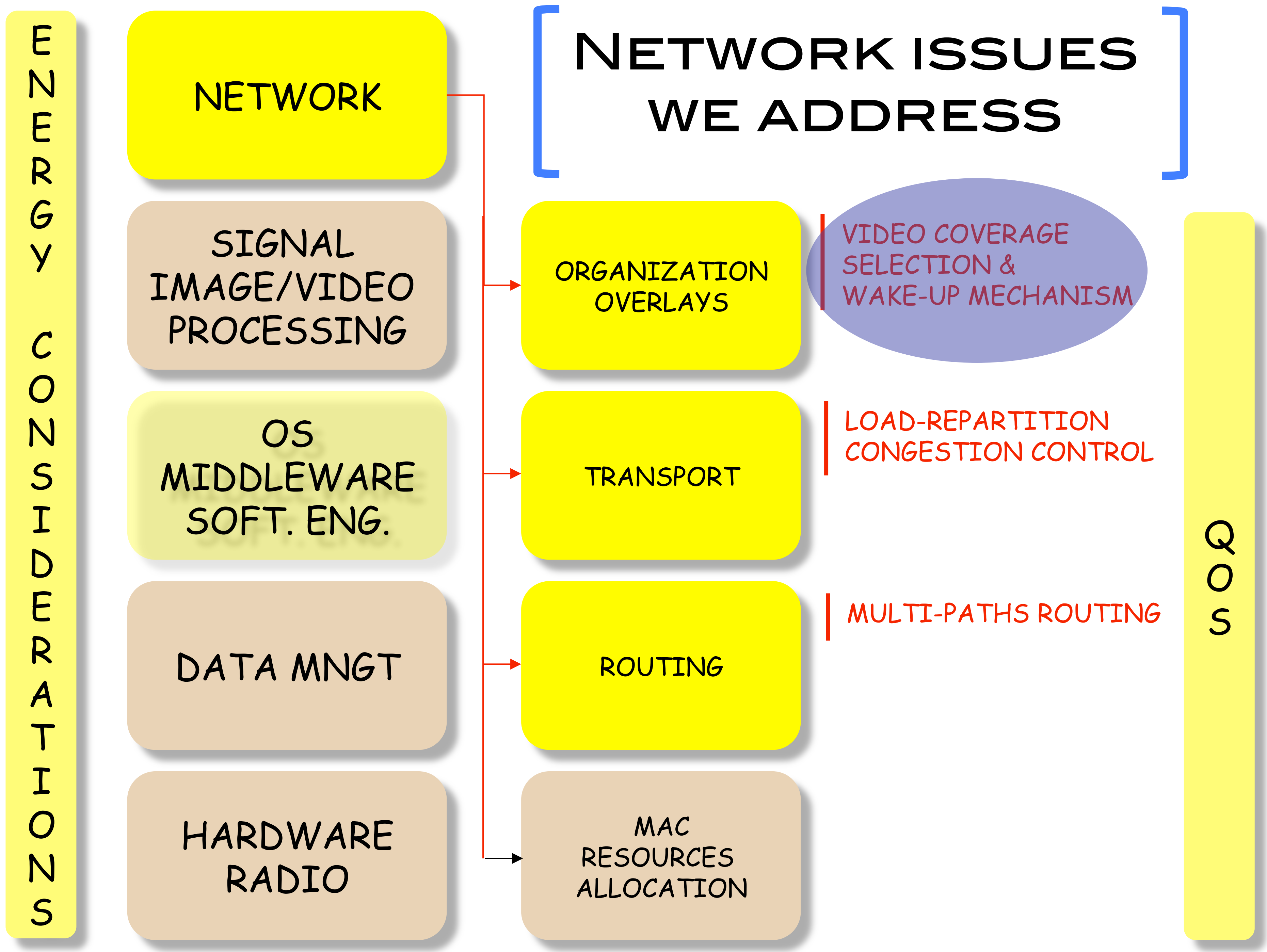
Node's cover set

- 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 $Co_i(v)$



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


MIDDLEWARE/APP. ISSUES WE ADDRESS
ENERGY CONSIDERATIONS
NETWORK
SIGNAL IMAGE/VIDEO PROCESSING
OS MIDDLEWARE SOFT. ENG.
DATA MNGT
HARDWARE RADIO
SENSOR'S OS
SUPERVISION PLATFORM
APPLICATIONS
CBSE for SENSOR NODE
DYNAMIC RECONFIGURATION
SERVICE-ORIENTED
SERVICE REPOSITORY
ADAPTIVE APPLICATION
QOS


ENERGY CONSIDERATIONS
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TRANSPORT
LOAD-REPARTITION
CONGESTION CONTROL
ROUTING
MULTI-PATHS ROUTING
MAC RESOURCES ALLOCATION
QOS

Criticality and risk-based scheduling

Don't miss important events!

Whole understanding of the scene is wrong!!!

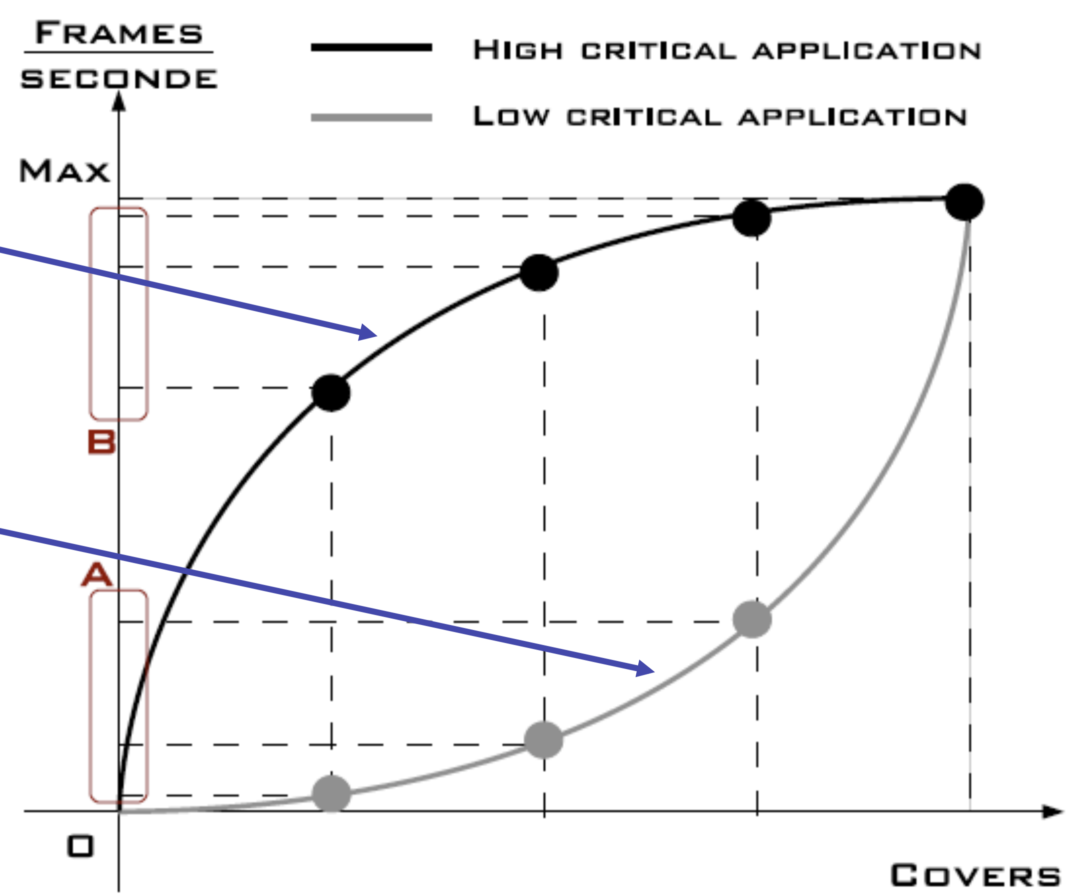
What is captured

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

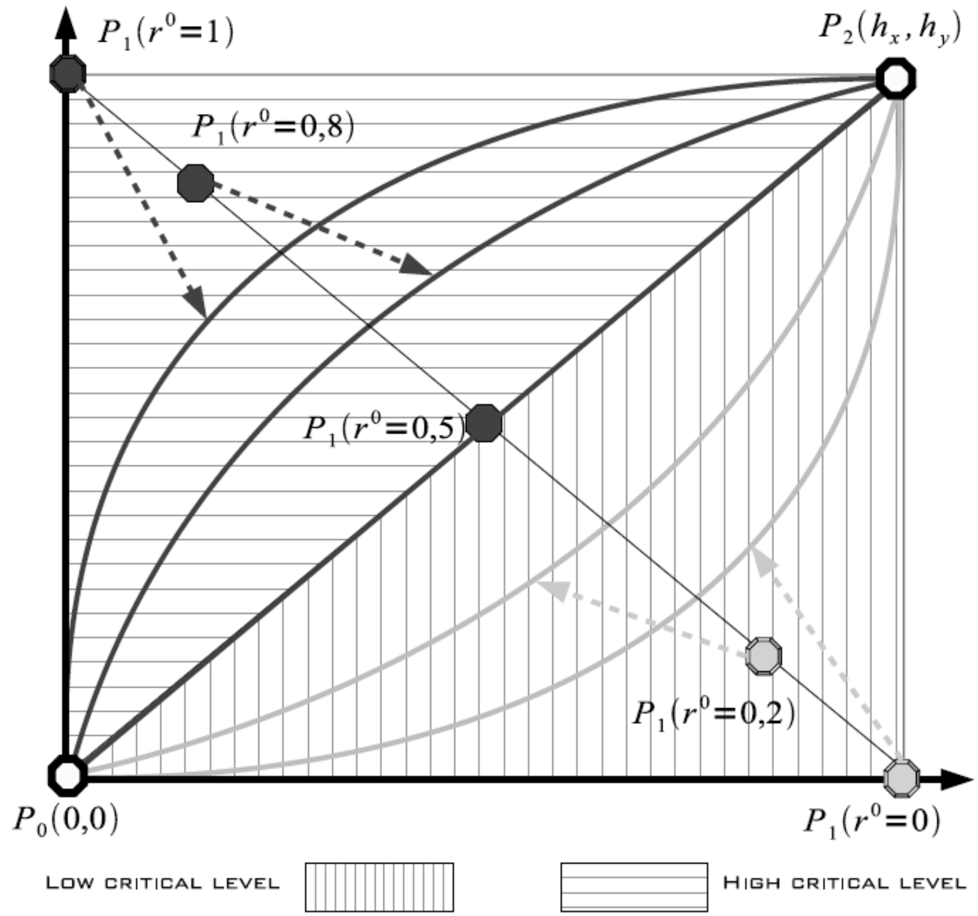
Criticality model (1)

- 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



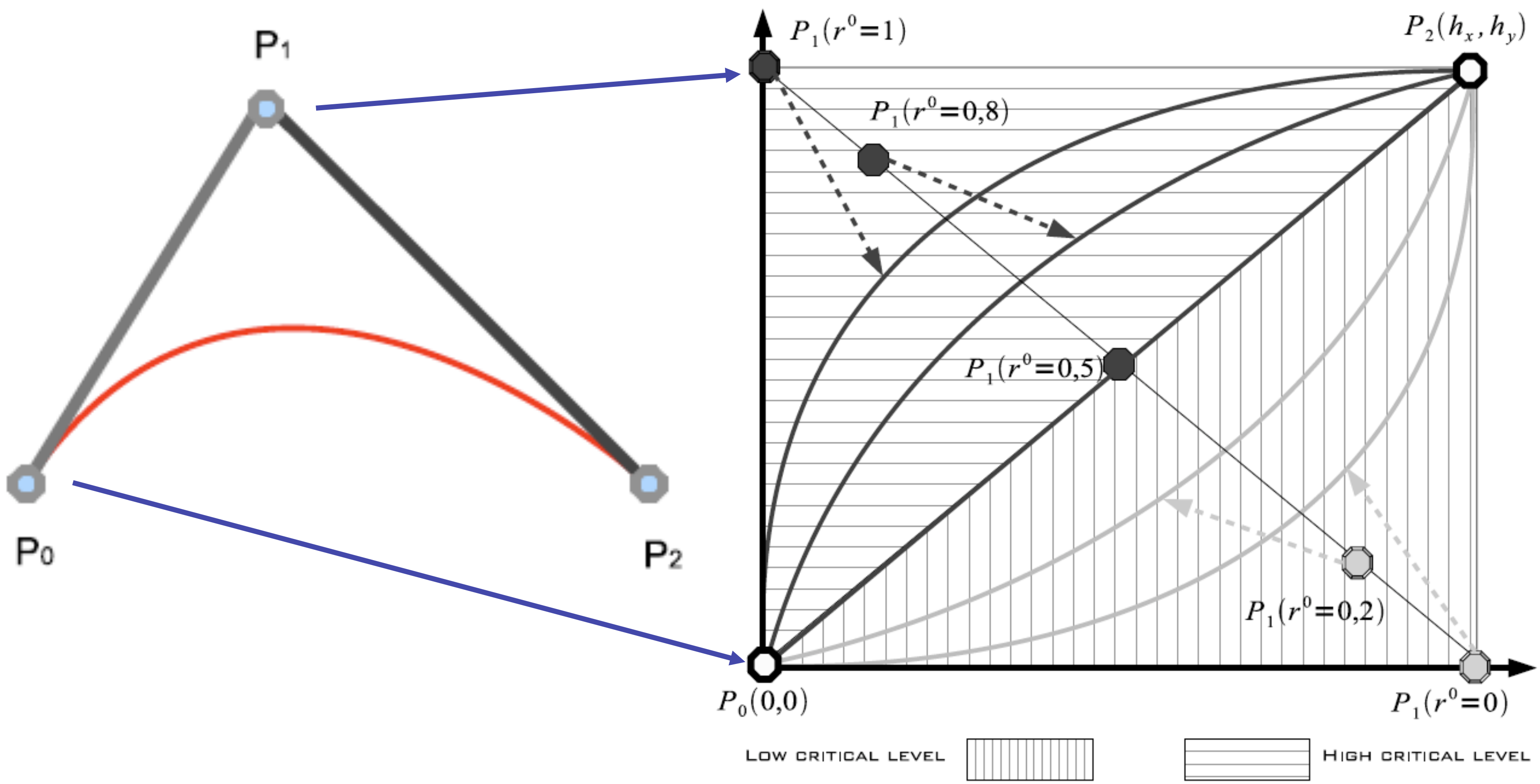
Criticality model (2)

- 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 Bezier 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 or 12fps
- Nodes with size of cover set greater than N capture at the maximum speed

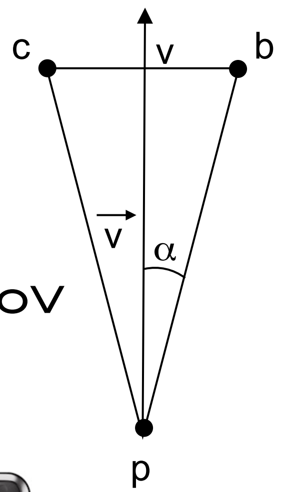
N=6
$P_2(6,6)$

r^0 \ $\|Co(v)\|$	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

N=12
$P_2(12,3)$

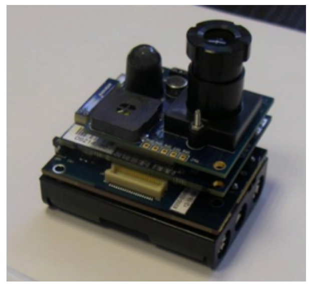
r^0	1	2	3	4	5	6	7	8	9	10	11	12
0	.01	.02	.05	0.1	.17	.26	.38	.54	.75	1.1	1.5	3
.2	.07	.15	.25	.37	.51	.67	.86	1.1	1.4	1.7	2.2	3
.4	.17	.35	.55	.75	.97	1.2	1.4	1.7	2.0	2.3	2.6	3
.6	.36	.69	1.0	1.3	1.5	1.8	2.0	2.2	2.4	2.6	2.8	3
.8	.75	1.2	1.6	1.9	2.1	2.3	2.5	2.6	2.7	2.8	2.9	3
1	1.5	1.9	2.2	2.4	2.6	2.7	2.8	2.9	2.9	2.9	2	3

Finding v's cover set

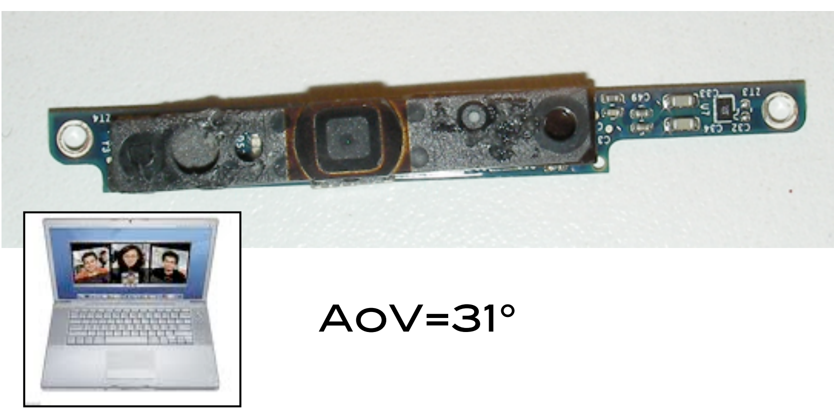


2α=AoV

AoV=20°

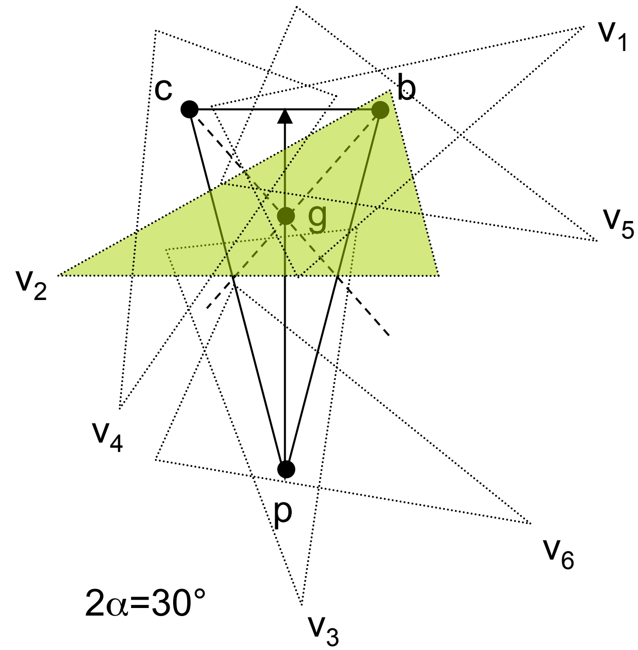


AoV=38°



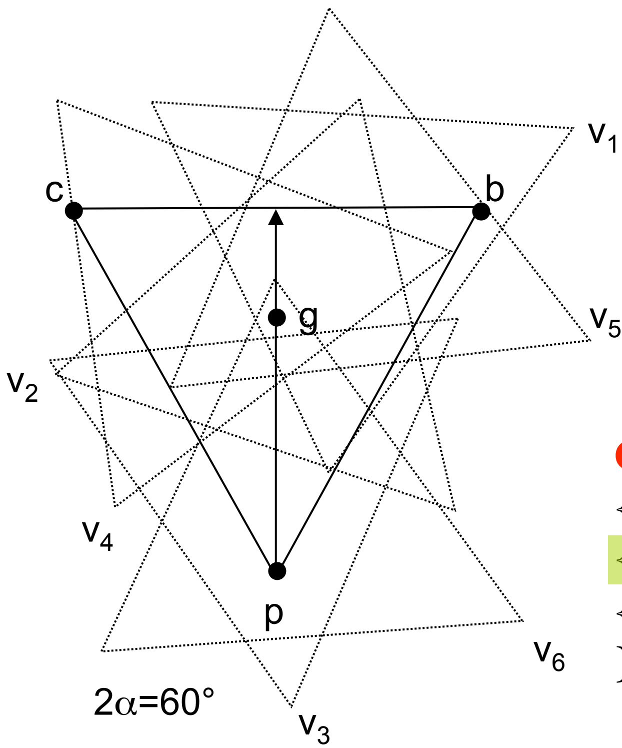
AoV=31°

P = {v ∈ N(V) : v covers the point "p" 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}

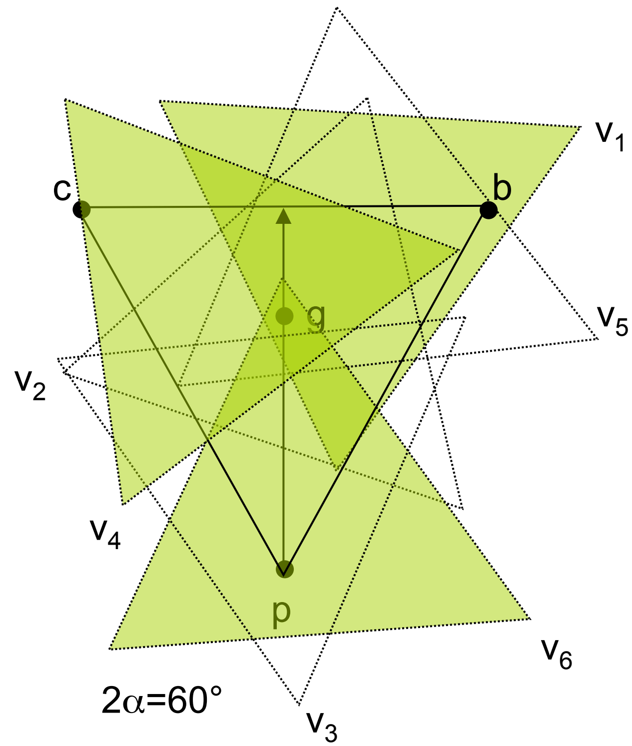


PG={P∩G}
BG={B∩G}
CG={C∩G}
Co(v)=PG×BG×CG

Large Angle of View

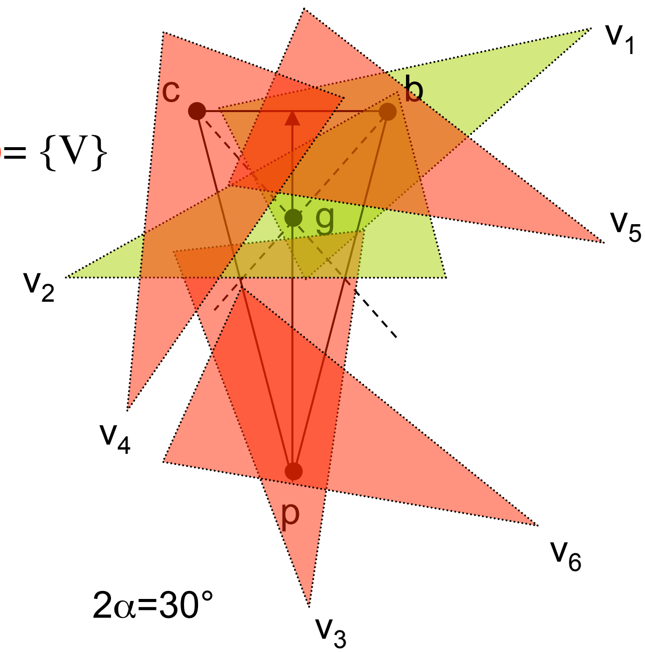


Co(V)= {
{V },
{V_1, V_4, V_6},
{V_4, V_5, V_6}
}

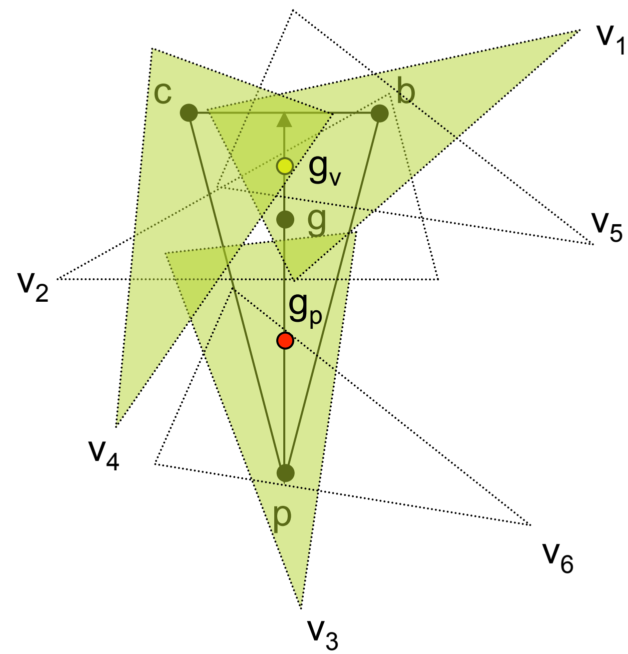


Small Angle of View

Co(V)= {V}

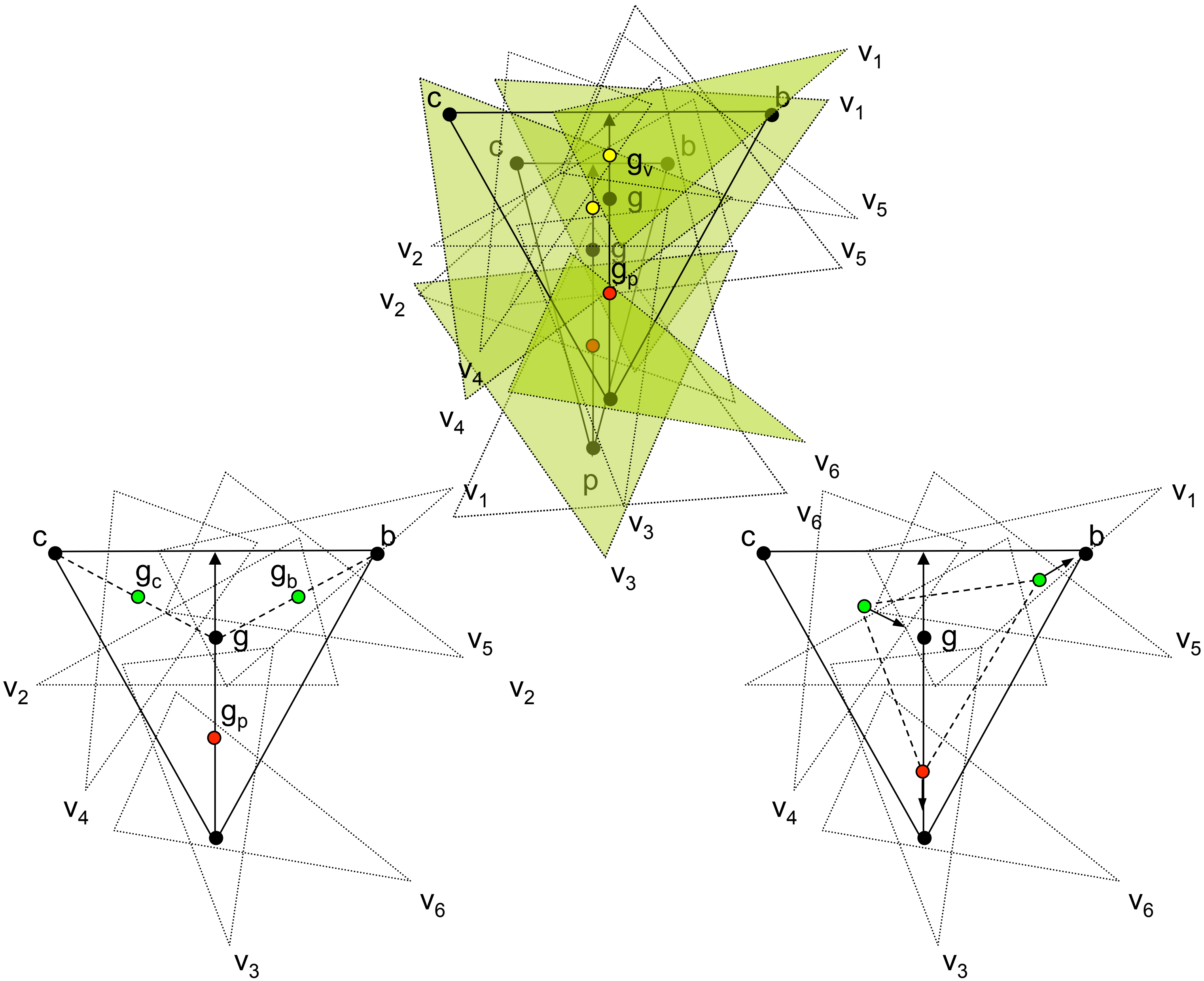


Co(V)= {
{V },
{V_1, V_3, V_4},
{V_2, V_3, V_4},
{V_3, V_4, V_5},
{V_1, V_4, V_6},
{V_2, V_4, V_6},
{V_4, V_5, V_6}
}



$PG=\{P \cap G_P\}$
$BG=\{B \cap G_V\}$
$CG=\{C \cap G_V\}$
$Co(V)=PG \times BG \times CG$

Heterogeneous AoV



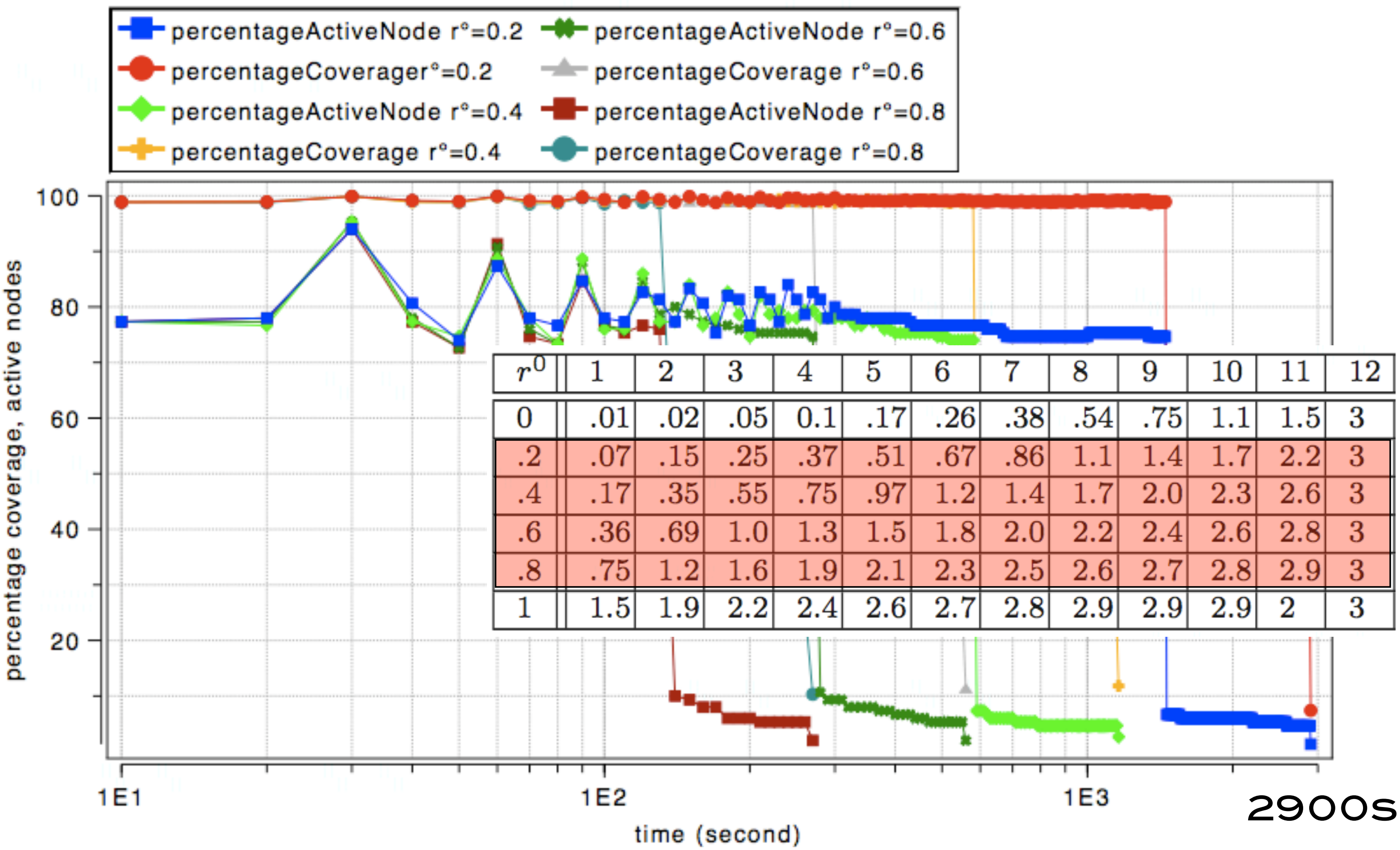
Simulation settings

- OMNET++ simulation model
- Video nodes have communication range of 30m and depth of view of 25m, AoV is 36°. 175 sensors in an 75m.75m area.
- Battery has 100 units, 1 image = 1 unit of battery consumed.
- Max capture rate is 3fps. 12 levels of cover set.
- Full coverage is defined as the region initially covered when all nodes are active

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

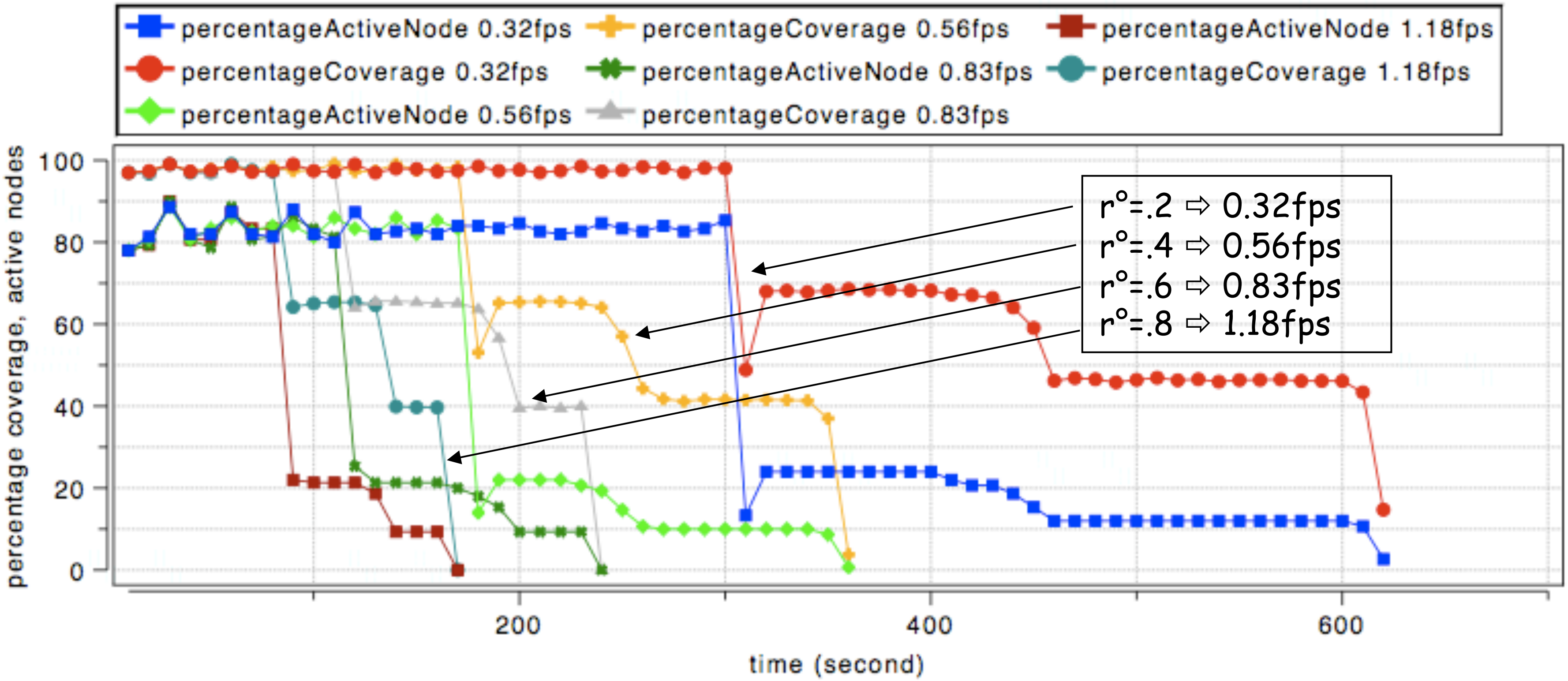
PERCENTAGE OF COVERAGE, ACTIVE NODES (1)



r^0	1	2	3	4	5	6	7	8	9	10	11	12
0	.01	.02	.05	0.1	.17	.26	.38	.54	.75	1.1	1.5	3
.2	.07	.15	.25	.37	.51	.67	.86	1.1	1.4	1.7	2.2	3
.4	.17	.35	.55	.75	.97	1.2	1.4	1.7	2.0	2.3	2.6	3
.6	.36	.69	1.0	1.3	1.5	1.8	2.0	2.2	2.4	2.6	2.8	3
.8	.75	1.2	1.6	1.9	2.1	2.3	2.5	2.6	2.7	2.8	2.9	3
1	1.5	1.9	2.2	2.4	2.6	2.7	2.8	2.9	2.9	2.9	2	3

2900s

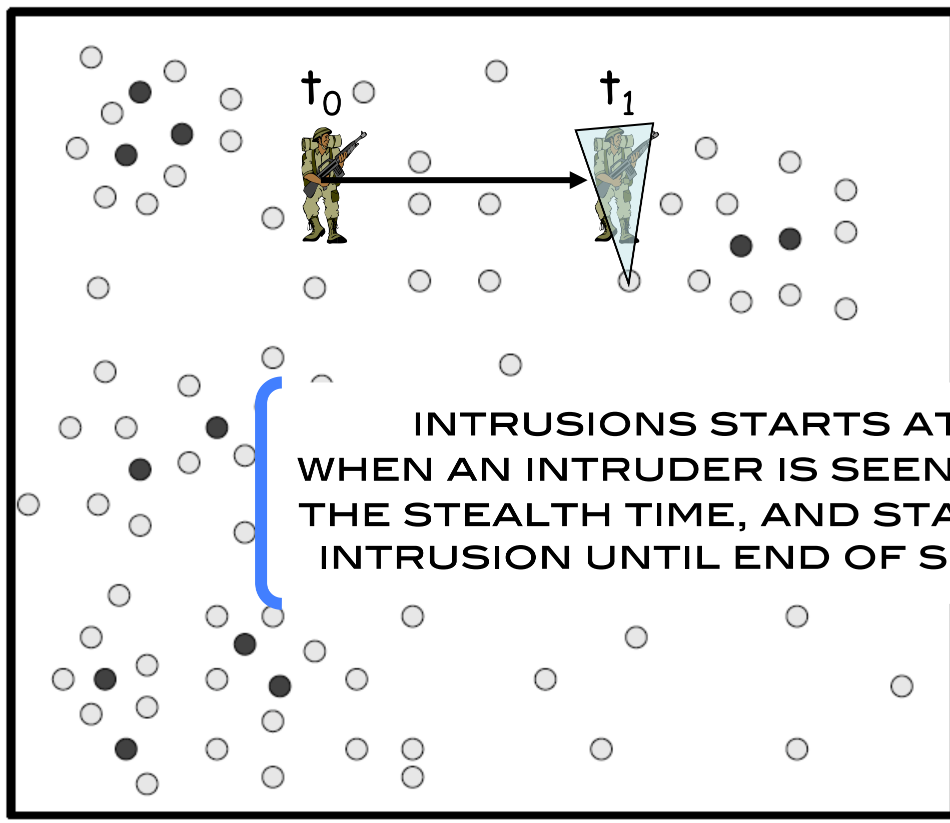
Percentage of coverage, active nodes (2)



In comparison, using a dynamic risk-based scheduling gives a network lifetime of nearly 2900s for r°=0.2

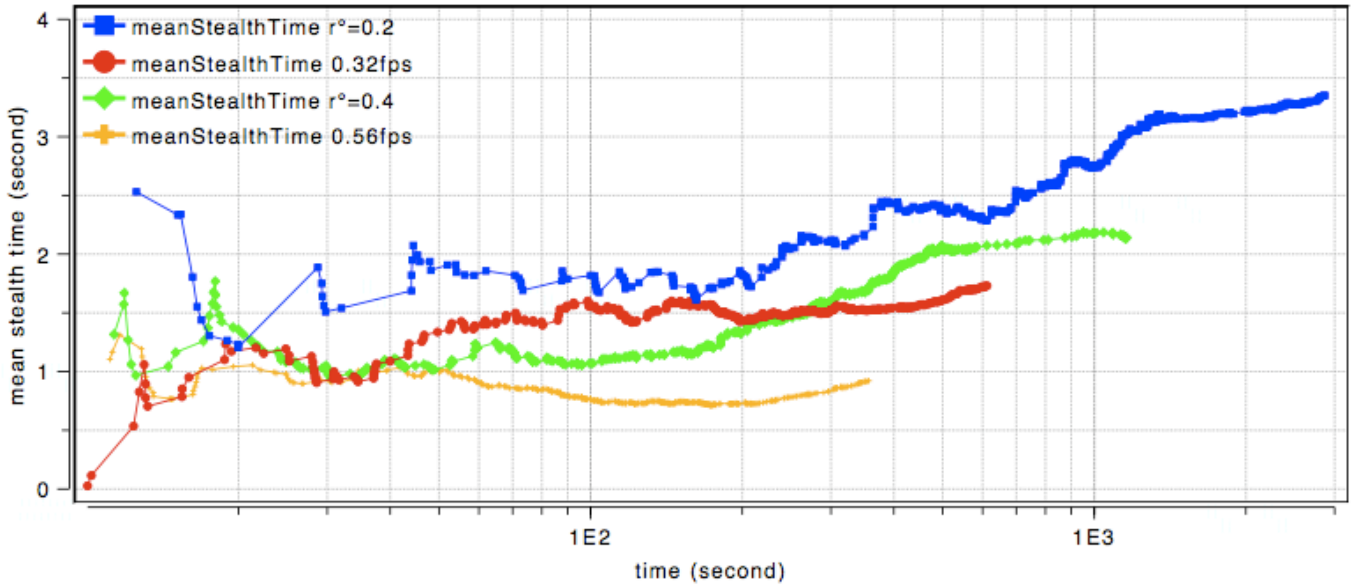
MEAN STEALTH TIME

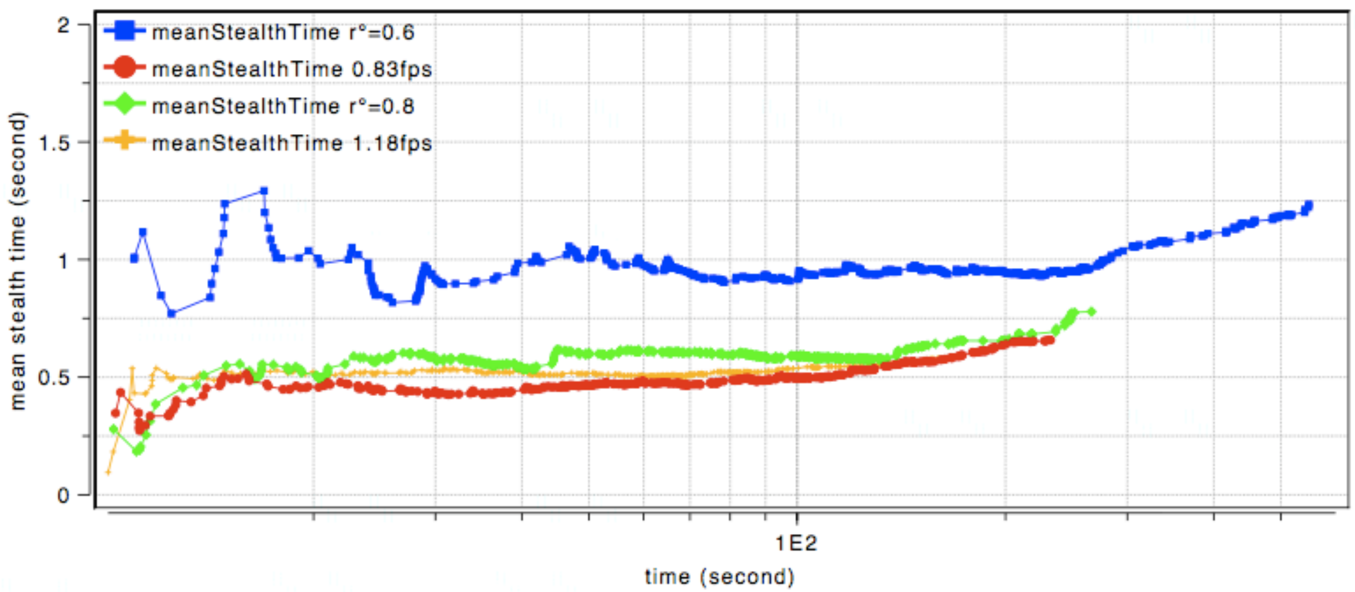
T_1-T_O IS THE INTRUDER'S STEALTH TIME
VELOCITY IS SET TO 5M/S



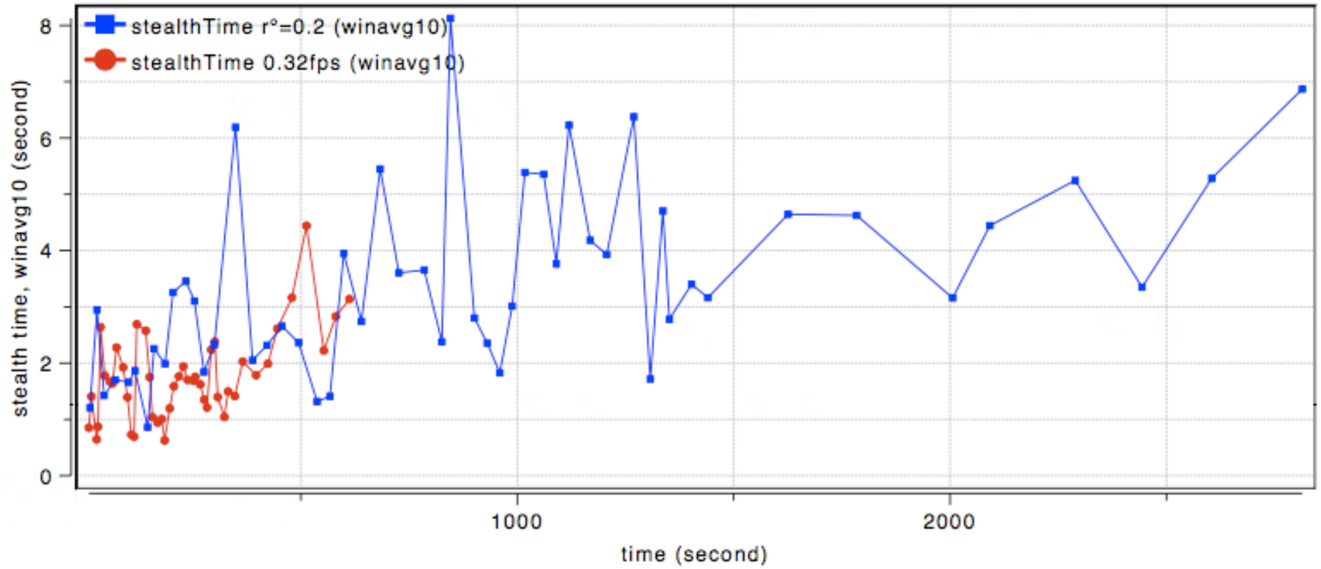
INTRUSIONS STARTS AT T=10S
WHEN AN INTRUDER IS SEEN, COMPUTE THE STEALTH TIME, AND STARTS A NEW INTRUSION UNTIL END OF SIMULATION

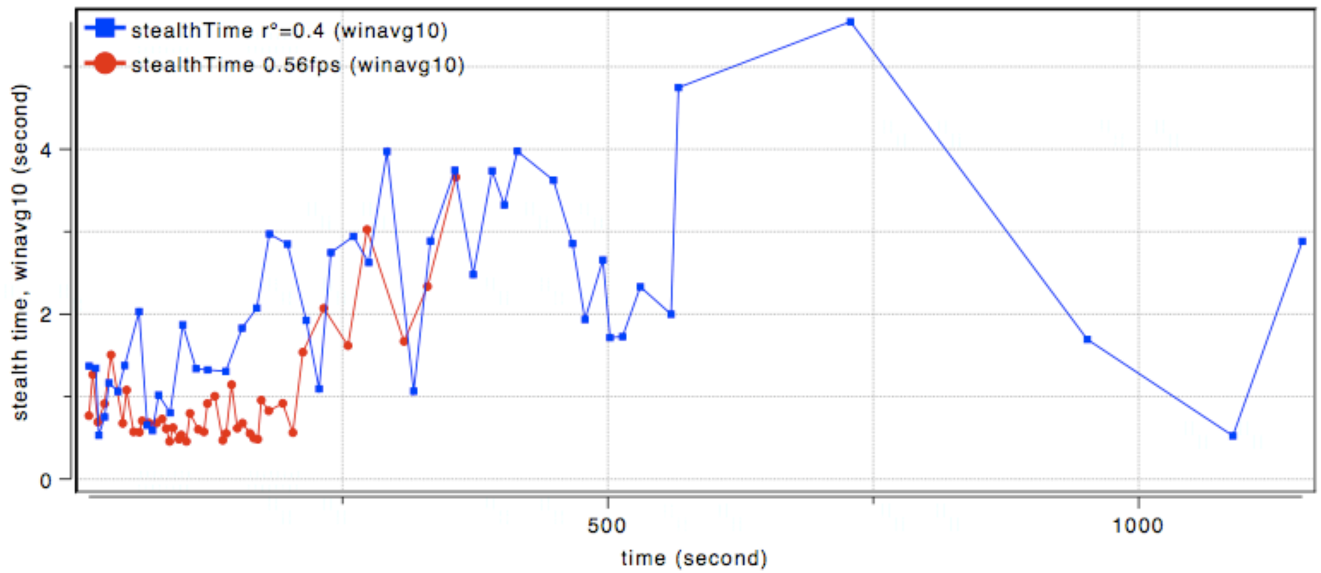
MEAN STEALTH TIME



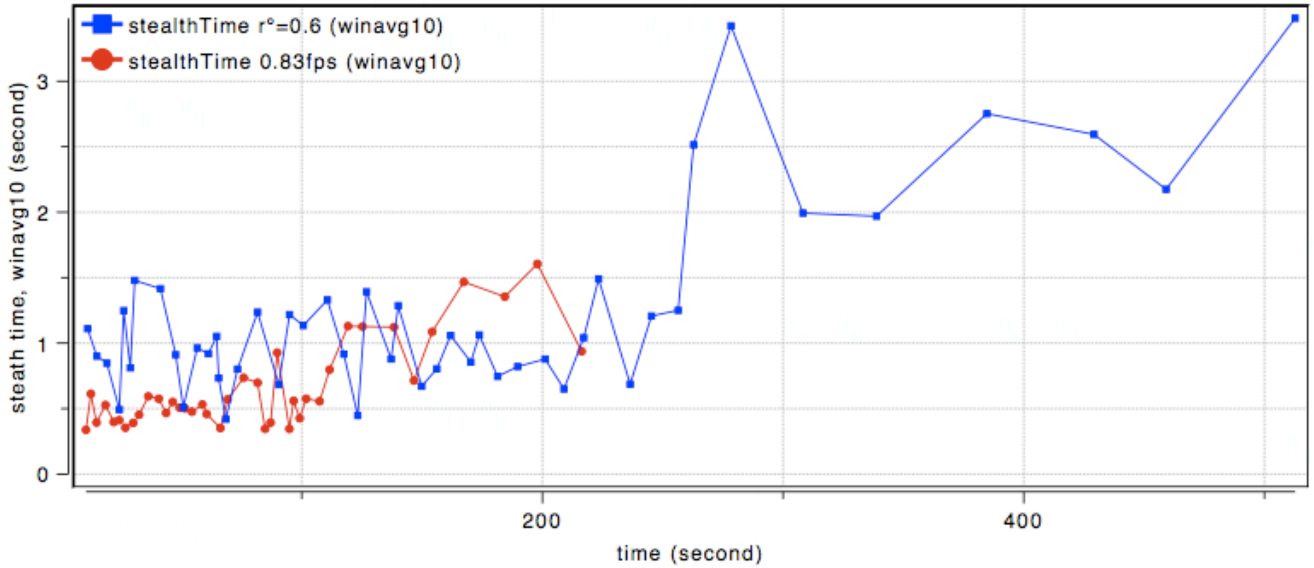


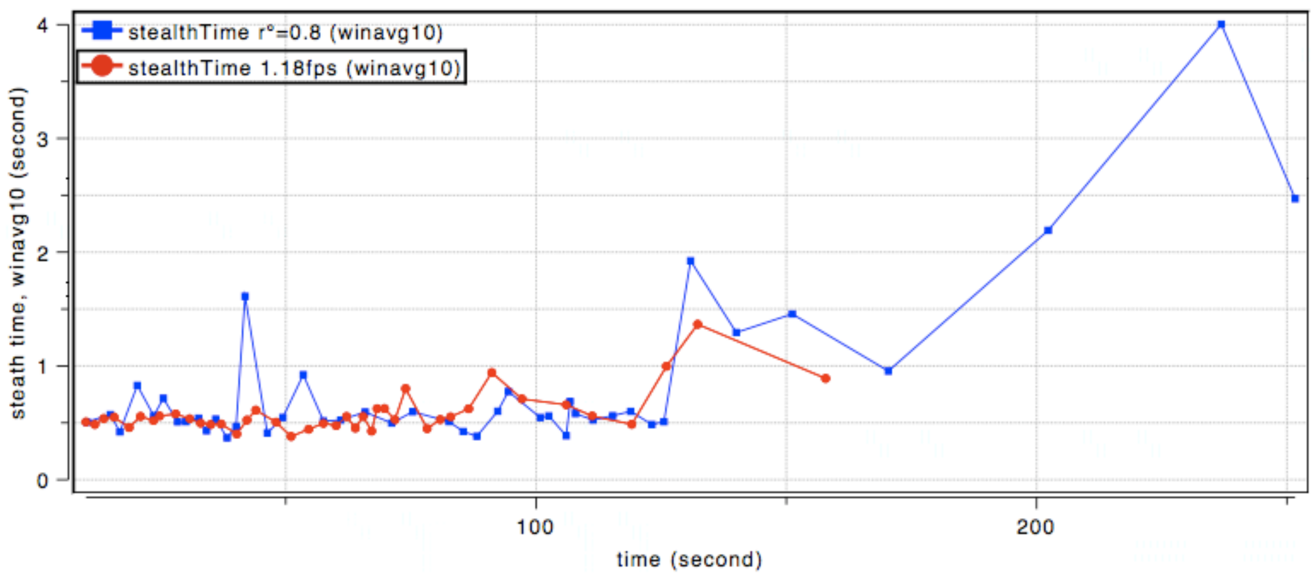
STEALTH TIME, WINAVG[10]





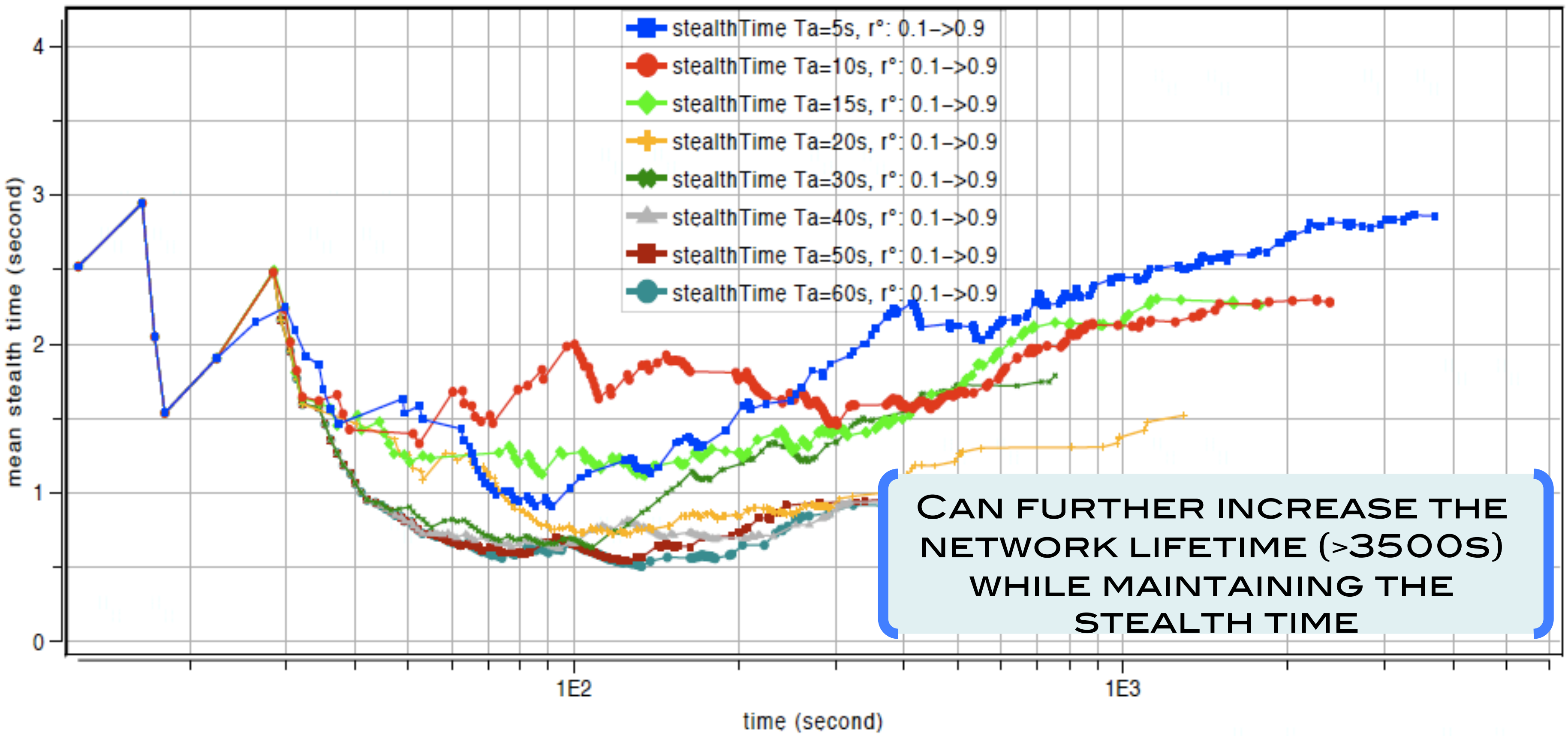
STEALTH TIME, WINAVG[10]





Dynamic scheduling

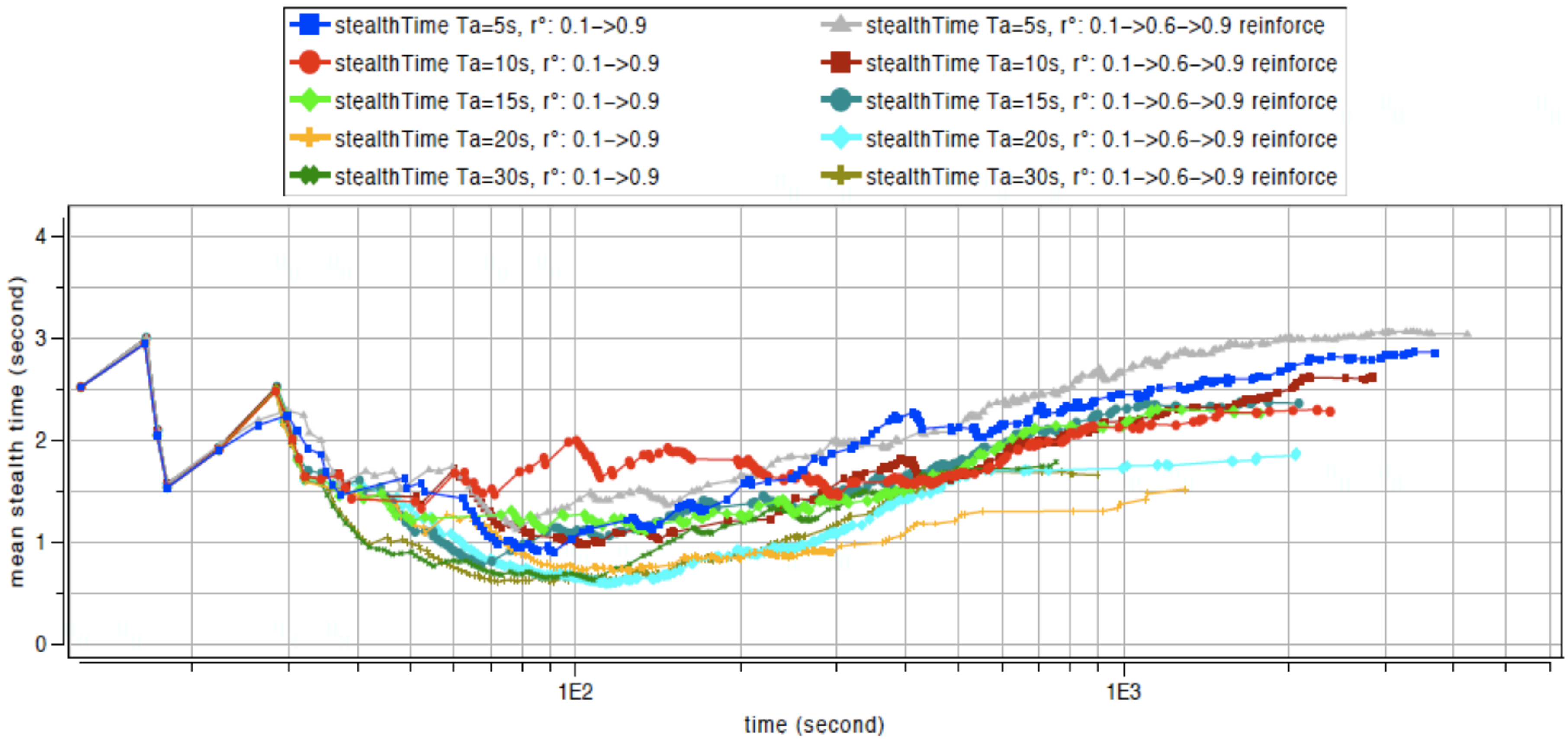
- $r° = 0.1$, $r_{MAX} = 0.9$, $T_A = 5,10,15,20..60s$



Can further increase the network lifetime (>3500s) while maintaining the stealth time

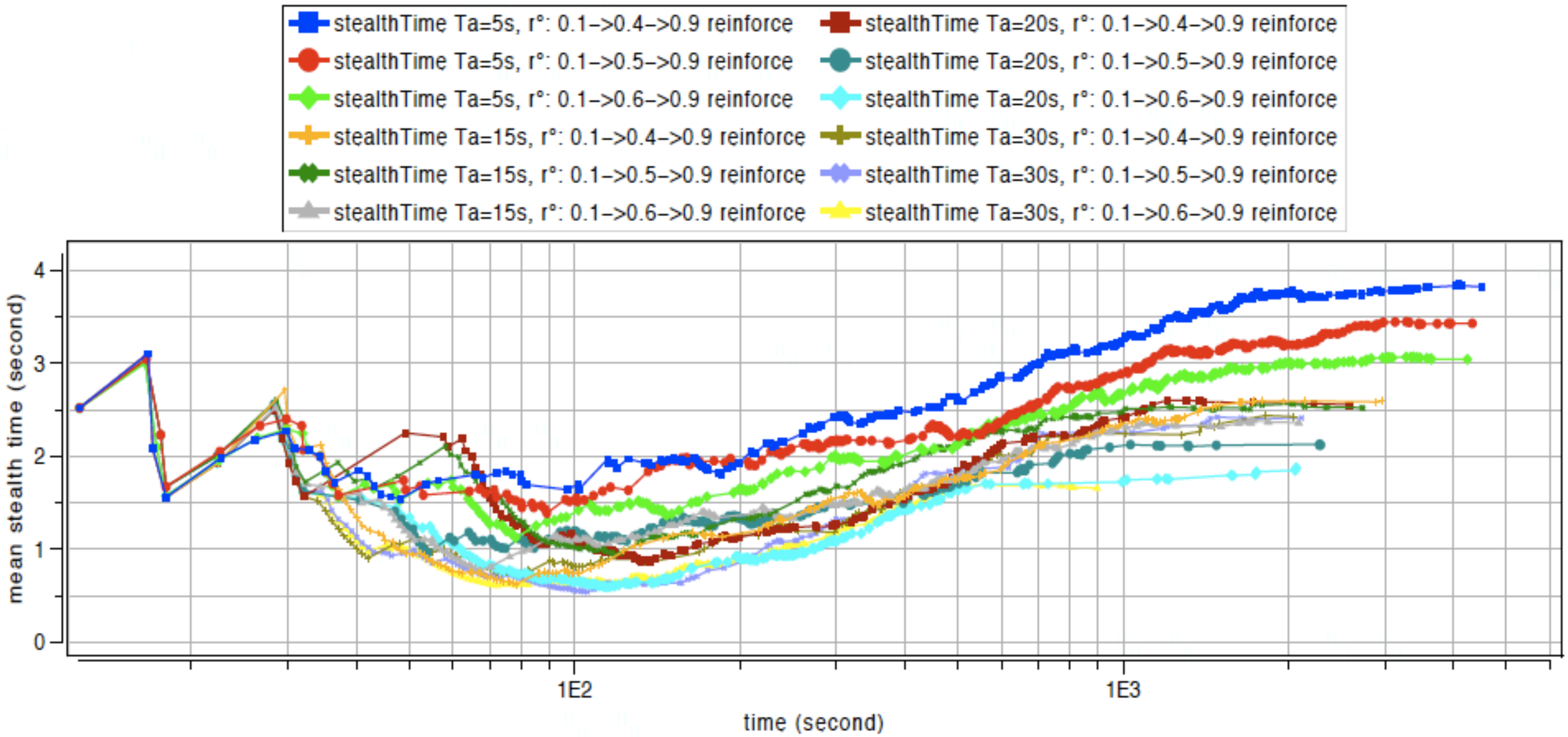
Dynamic with reinforcement (1)

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



Dynamic with reinforcement (2)

- R°=0.1→I_R=0.4/0.5/0.6→R_{MAX}=0.9
- 2 alert msg to have I_R=I_R+0.1



The advantage of having more cover-set (1)

N=6

$P_2(6,6)$

r^0 \ $\|Co(v)\|$	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

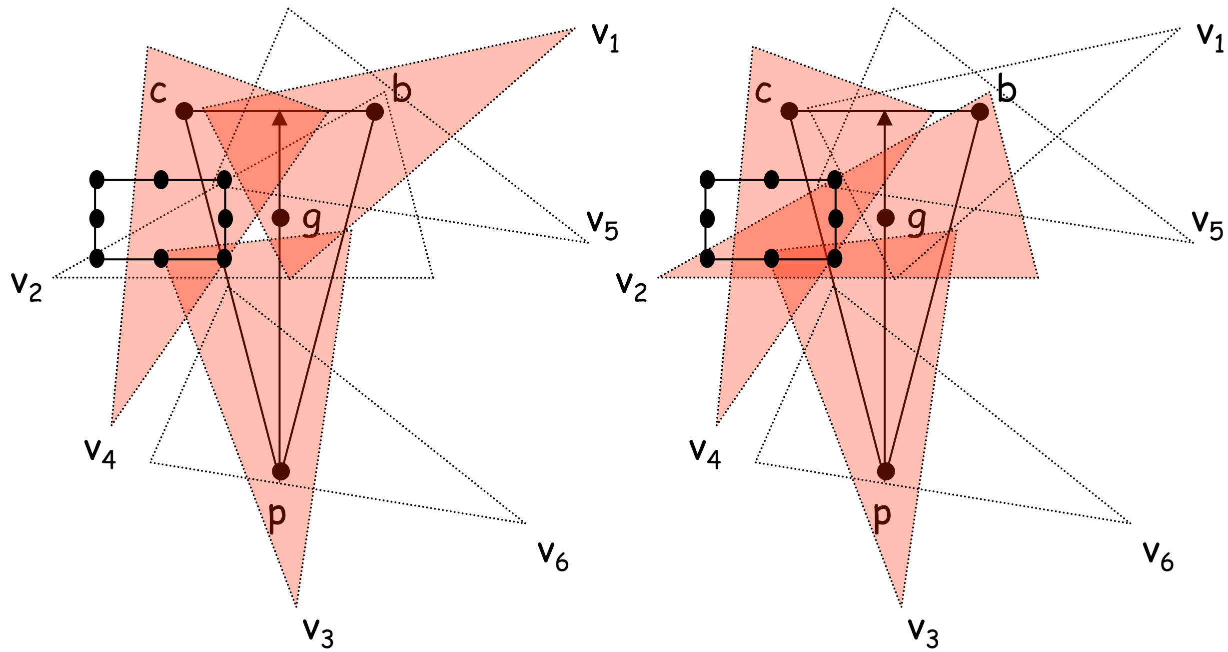
N=12

$P_2(12,3)$

r^0	1	2	3	4	5	6	7	8	9	10	11	12
0	.01	.02	.05	0.1	.17	.26	.38	.54	.75	1.1	1.5	3
.2	.07	.15	.25	.37	.51	.67	.86	1.1	1.4	1.7	2.2	3
.4	.17	.35	.55	.75	.97	1.2	1.4	1.7	2.0	2.3	2.6	3
.6	.36	.69	1.0	1.3	1.5	1.8	2.0	2.2	2.4	2.6	2.8	3
.8	.75	1.2	1.6	1.9	2.1	2.3	2.5	2.6	2.7	2.8	2.9	3
1	1.5	1.9	2.2	2.4	2.6	2.7	2.8	2.9	2.9	2.9	2	3

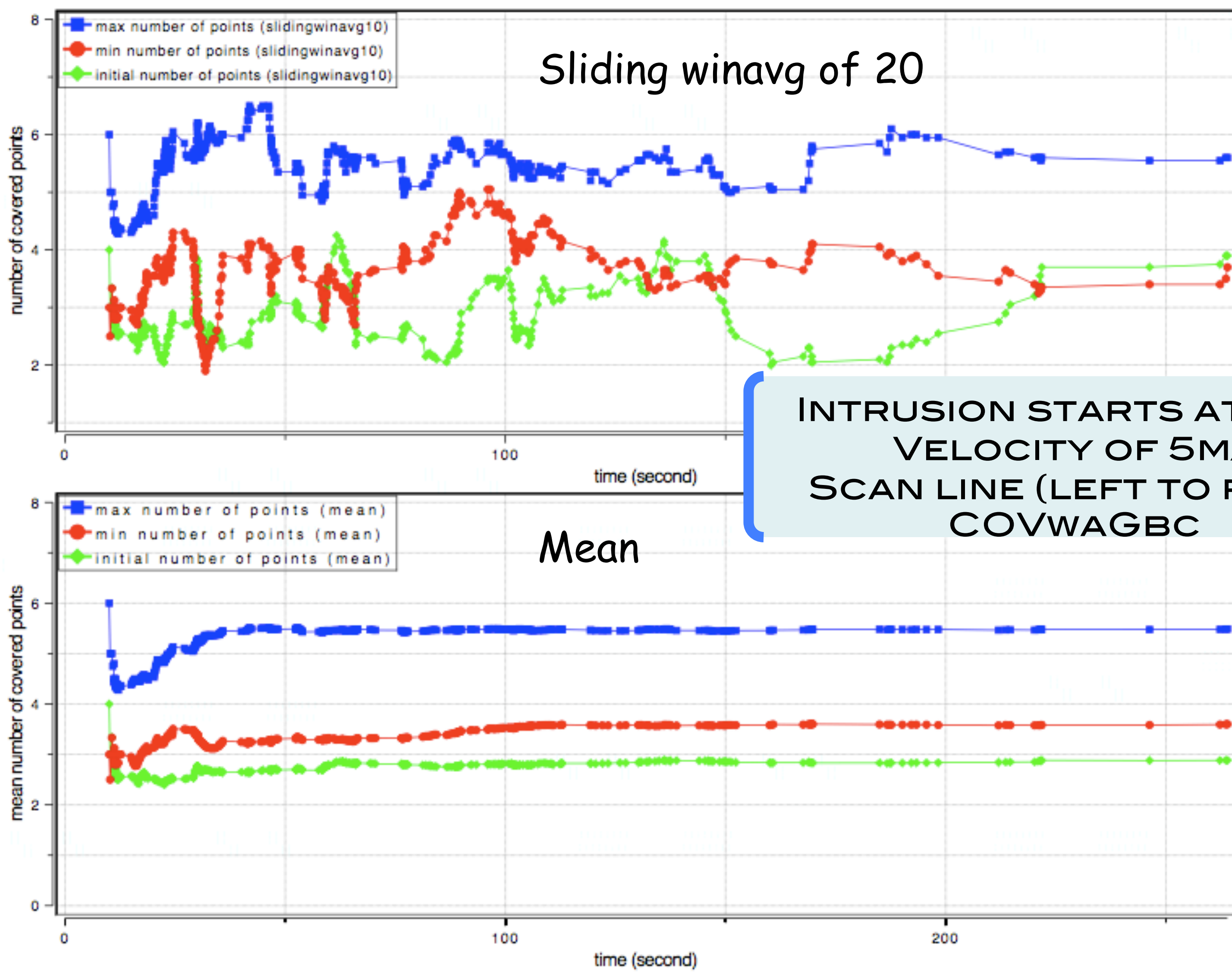
Occlusions/ Disambiguation

8m.4m rectangle→grouped intrusions



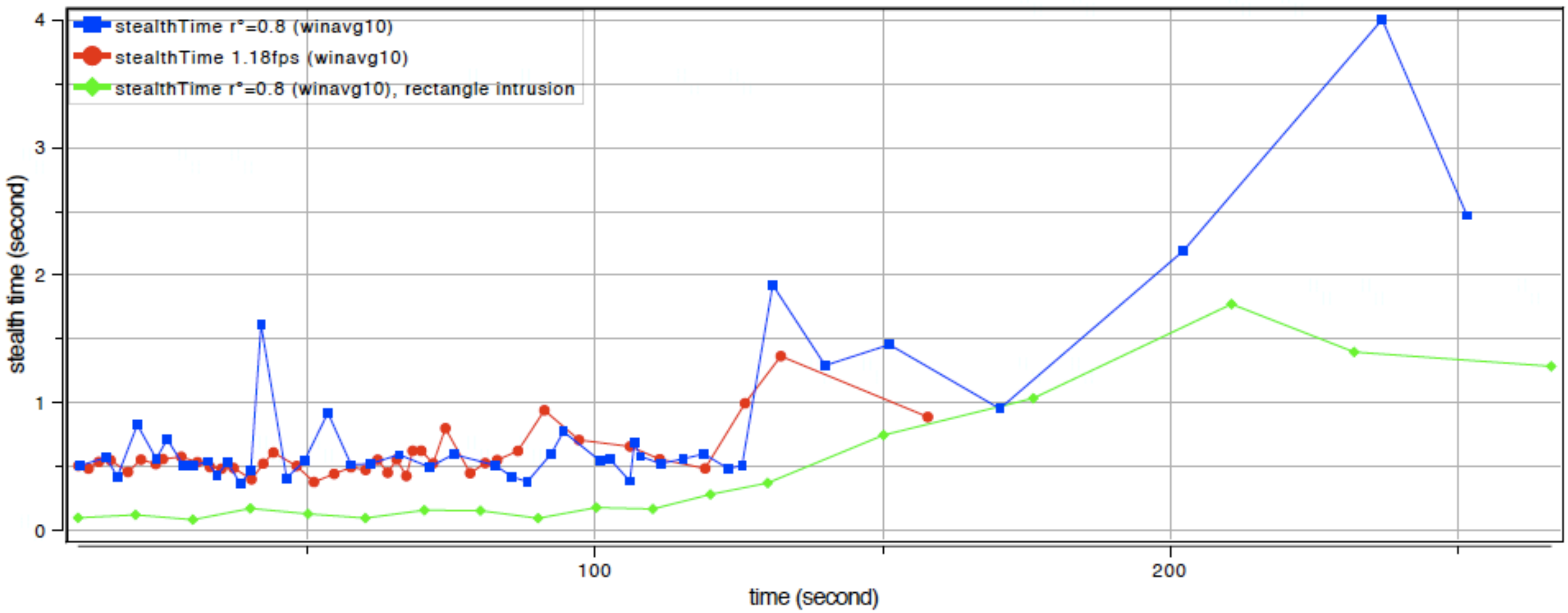
Multiple viewpoints are desirable
Some cover-sets « see » more points than other

The advantage of having more cover-set (2)



Intrusion starts at t=10s
Velocity of 5m/s
Scan line (left to right)
COVwaGbc

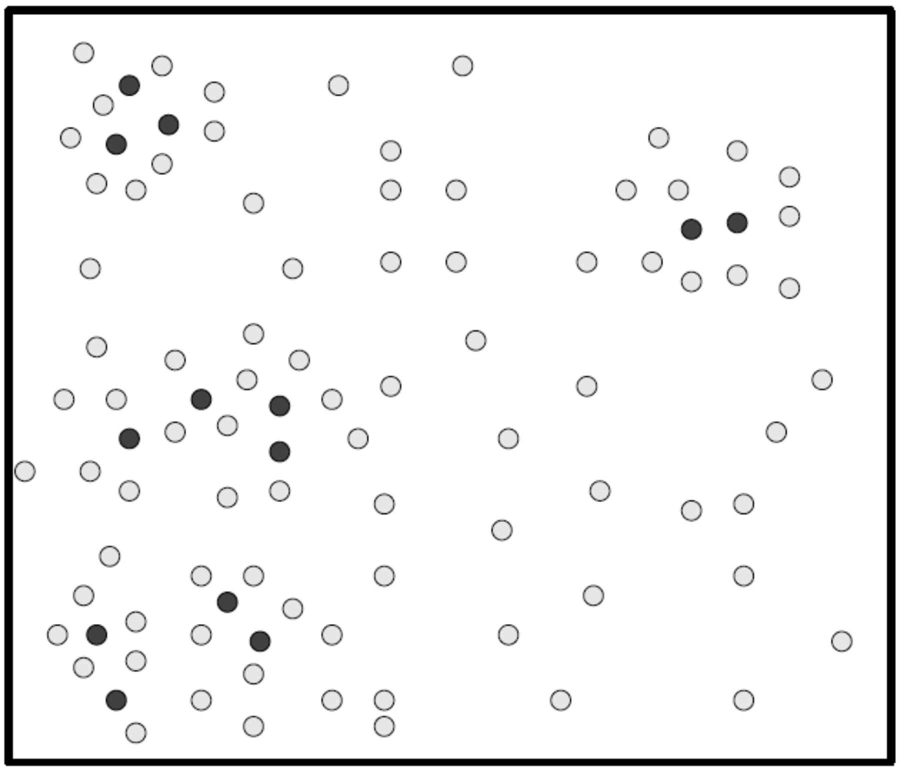
Stealth time with grouped intrusions



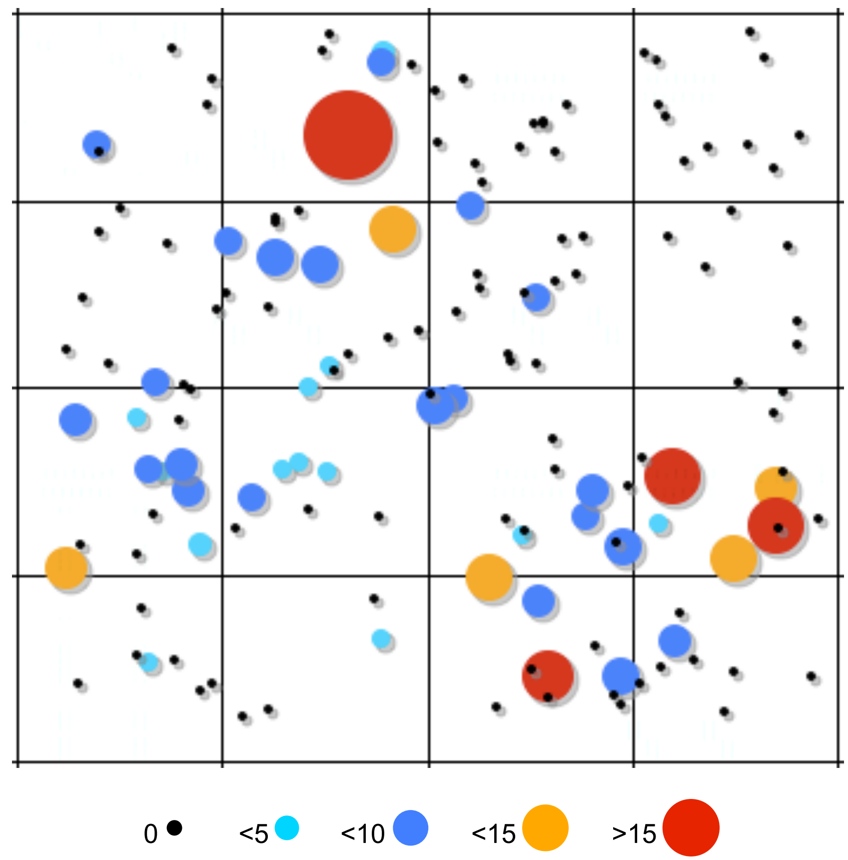
[Defining sentry nodes]

● Sentry node: node with high speed capture (high cover set).

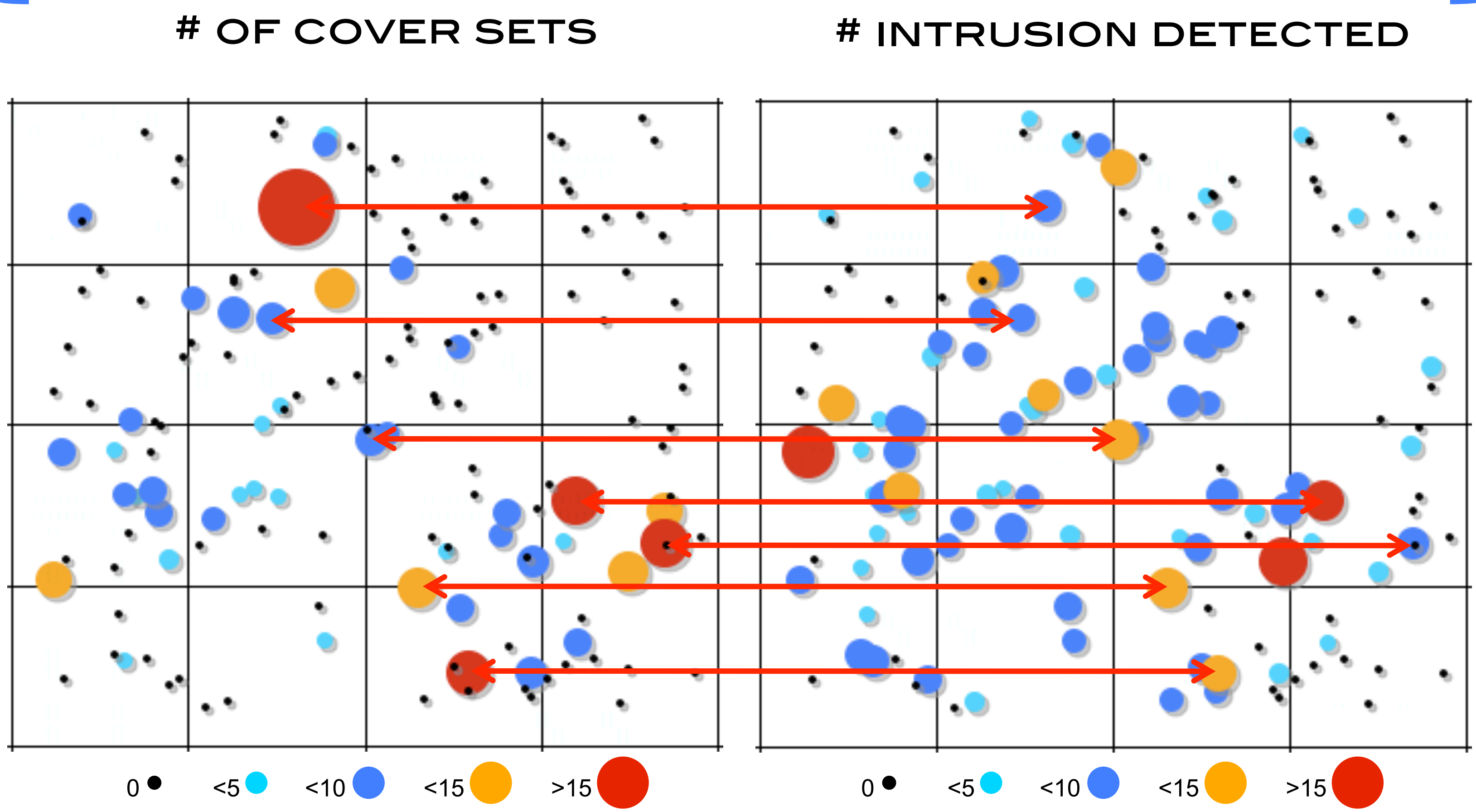
○ Idle node: node with low speed capture.



# of cover sets



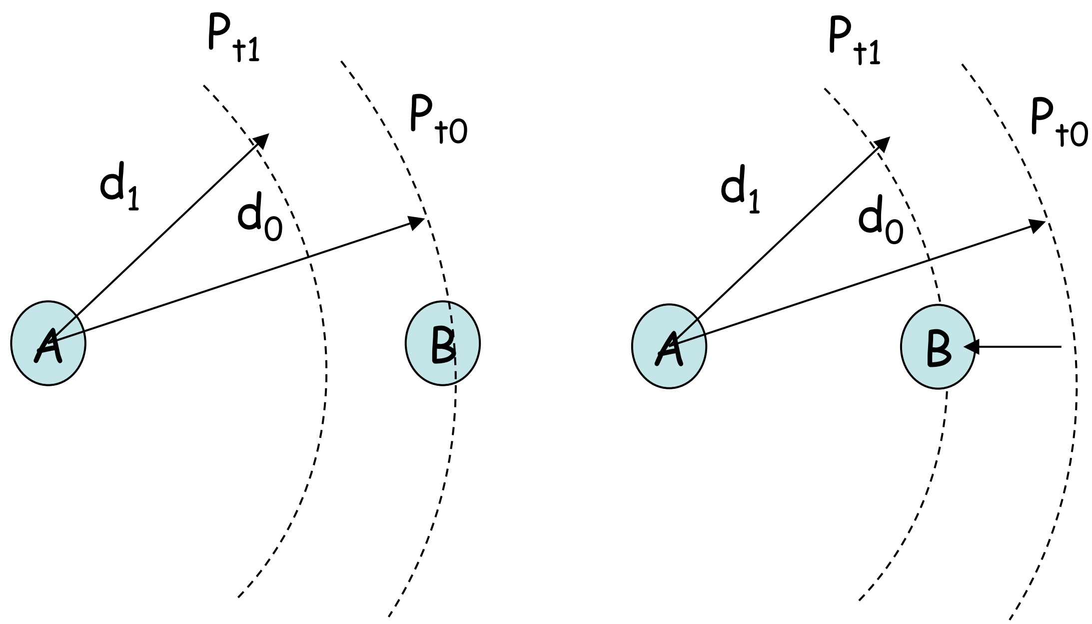
Sentry nodes



Sensor mobility

Introducing mobility

- To improve coverage
- To reduce energy-consumption



Practical mobility constraints

Transmission power levels

Register code	TX RF Power (dBm)	TX RF Power (mW)
31	0	1
27	-1	0.7943
23	-3	0.3162
19	-5	0.2512
15	-7	0.1995
11	-10	0.1000
7	-15	0.0631
3	-25	0.0032

MICAz

Maximum distance of the receiver

TX RF Power (mW)	distance	difference
1	100m	0m
0.7943	89.13	10.87m
0.3162	70.79	18.33m
0.2512	56.23	14.56m
0.1995	44.67	11.57m
0.1000	31.62	13.05m
0.0631	17.78	13.84m
0.0032	5.62	12.16m

Mobility is justified when the energy of transmission for long-lived flows (video) can be decreased when the receivers are closer to the source

Preliminary model (1)

- Optimization problem of energy consumption, with coverage constraints and mobility constraints
- ILP techniques to model the constraints, then solve using Cplex
- A sensor's move is assumed to drain much more energy than transmission for the same distance

$$\forall i, j, i', j' : m_{i,j,i',j'} / c_{i,j,i',j'} = \rho > 1$$

Preliminary model (2)

- Coverage constraints imposes a given number of sensors/area

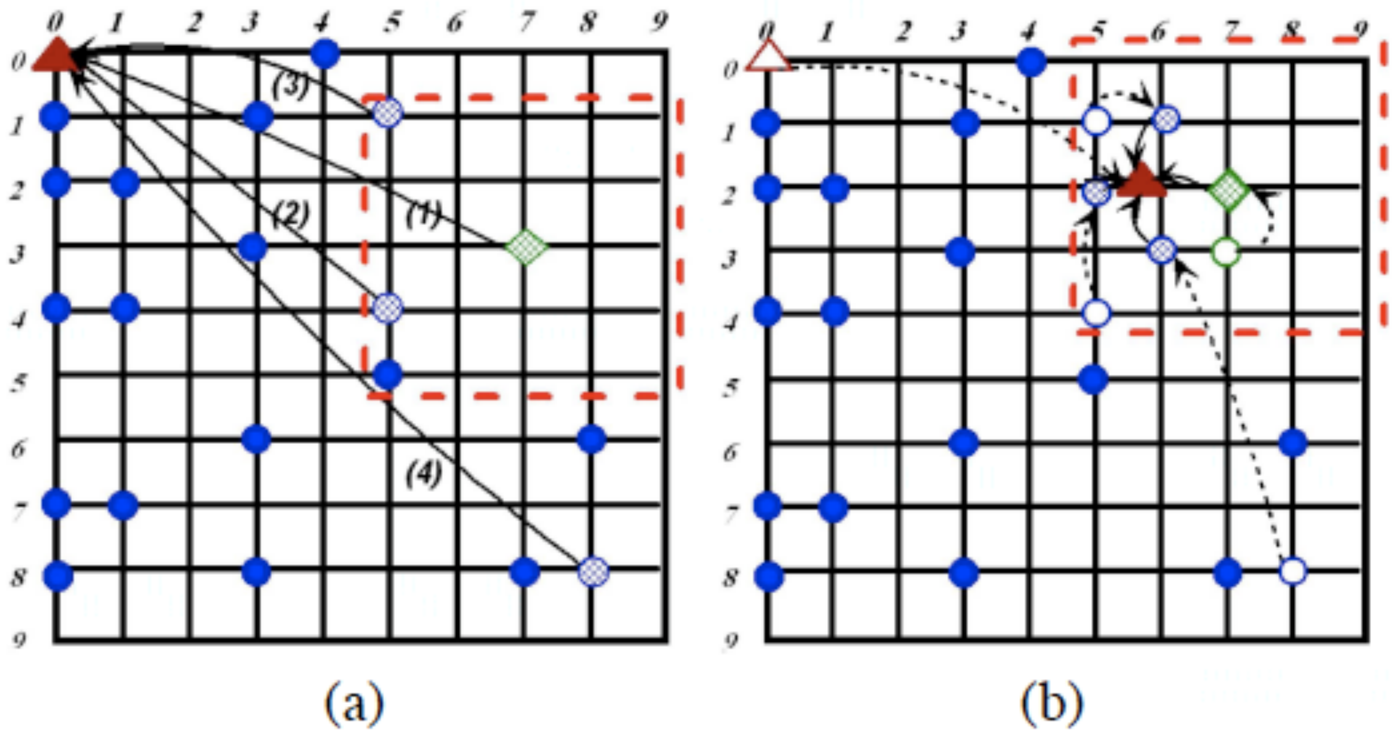
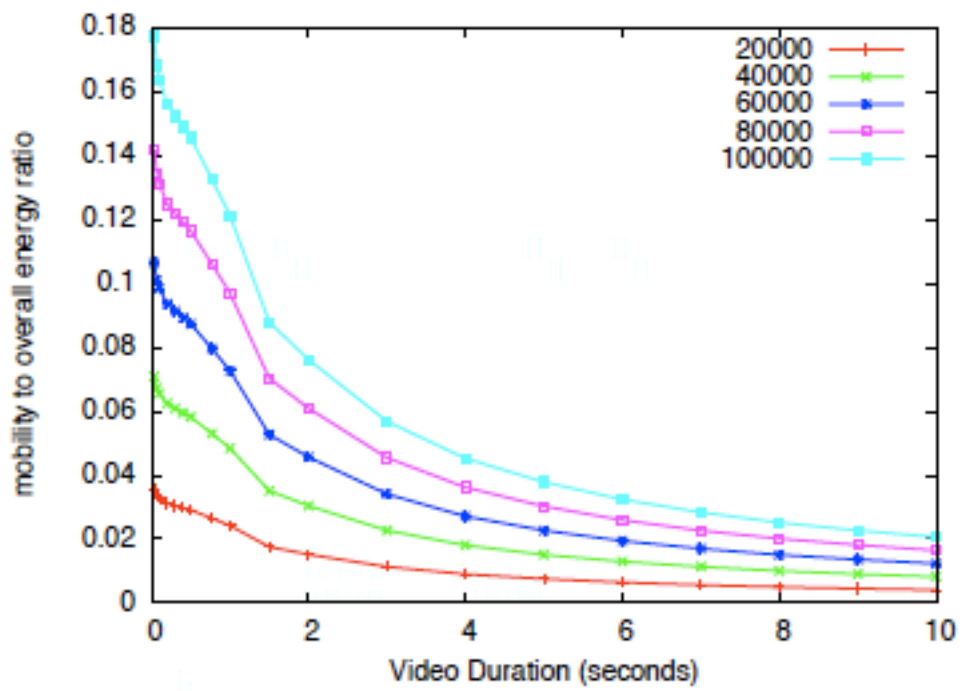


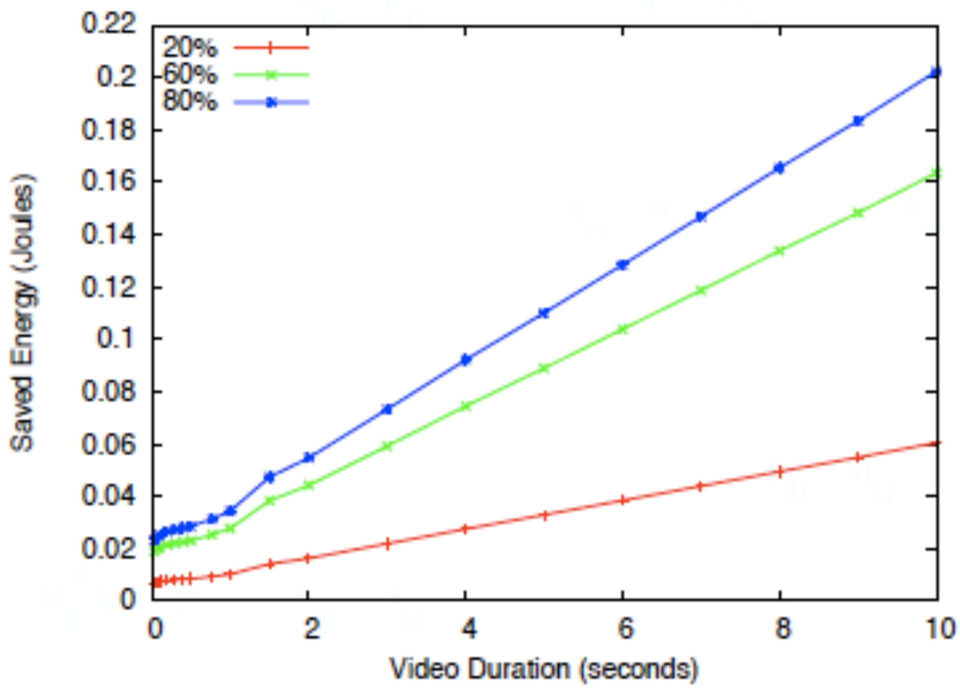
Fig. 5. Illustrative Example: coverage and connectivity constraints

Preliminary results on sensor's mobility

- 40 nodes, 20% are mobile
- 10x10 area grid system
- ρ is the cost ratio of mobility to communication per bit, $\rho>1$

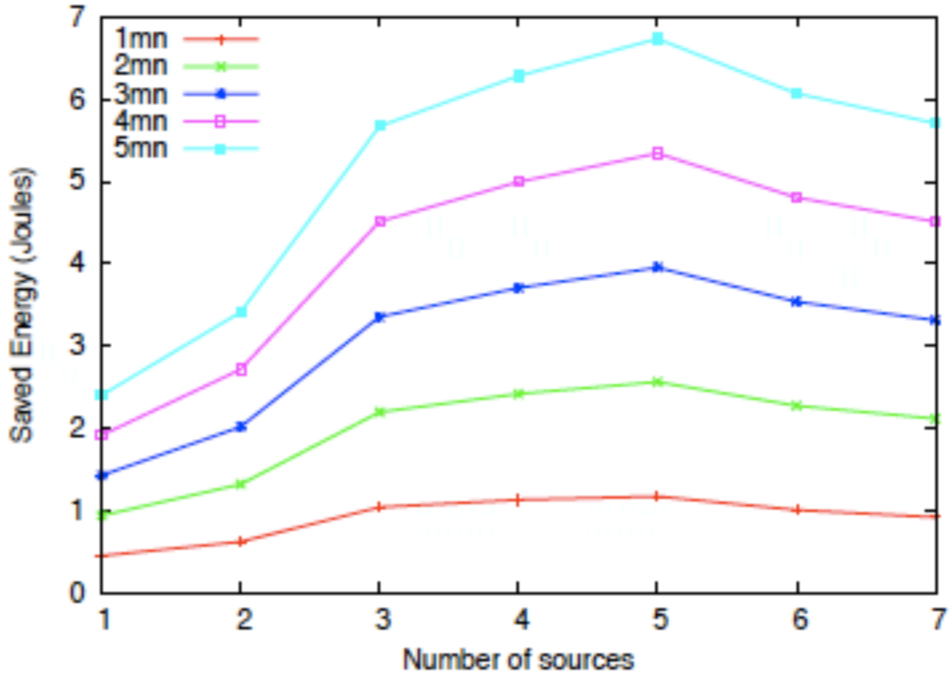


Varying the mobile node proportion



$\rho = 1000$

Varying the number of video sources



$\rho = 1000$

Conclusions

- Simple method for cover-set computation for video sensor node
- Takes into account small AoV and AoV heterogeneity
- Used jointly with a criticality-based scheduling, can increase the network lifetime while maintaining a high level of service (mean stealth time)

Perspectives

- Study the interactions of mobile nodes and fixed nodes, under the criticality management schemes
  - Mobile nodes could allow neighboring sensors to decrease their criticality level, even on alert
  - Information dissimination process
- Some mobility can be triggered by alerts
  - X% of mobile nodes can only move on alerts
- What trajectory for mobile nodes? What functionality?
  - Mobile nodes as relay
  - Mobile nodes as aggregators
  - Mobile nodes as validators