QoS and energy aspects in mission-critical applications with wireless sensors

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Energy Aware Network workshop

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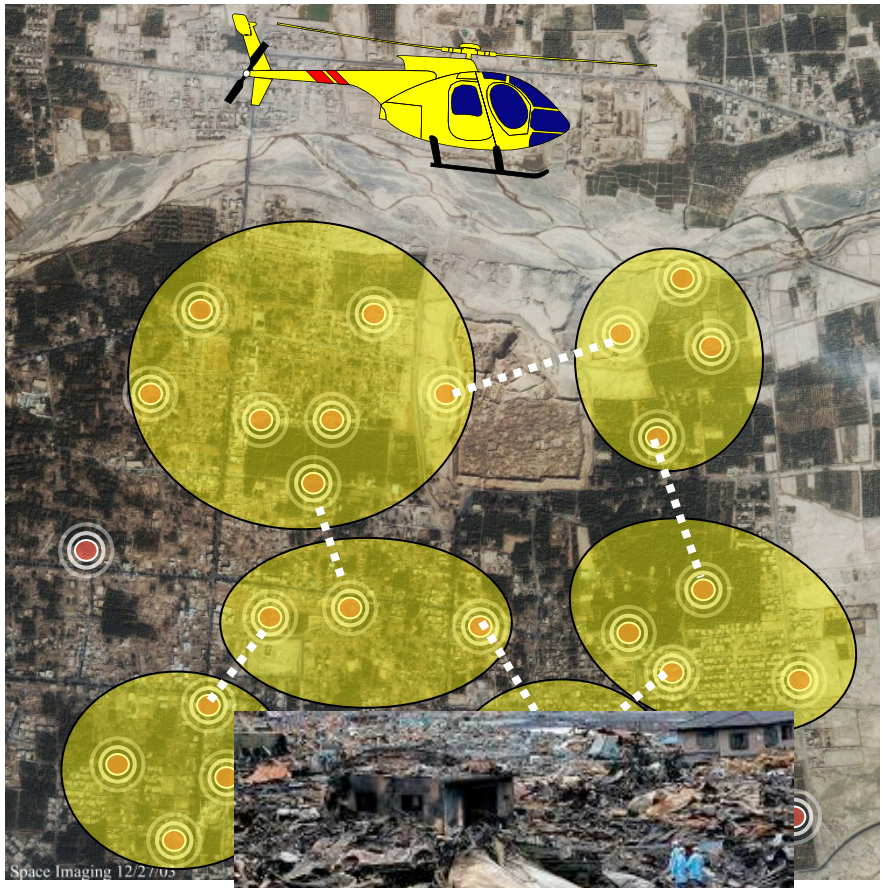
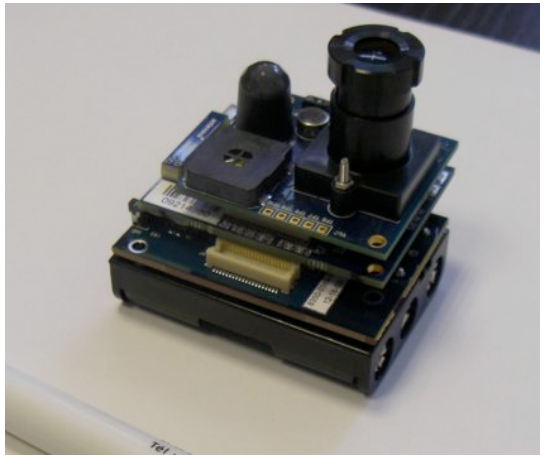
Mission-critical apps



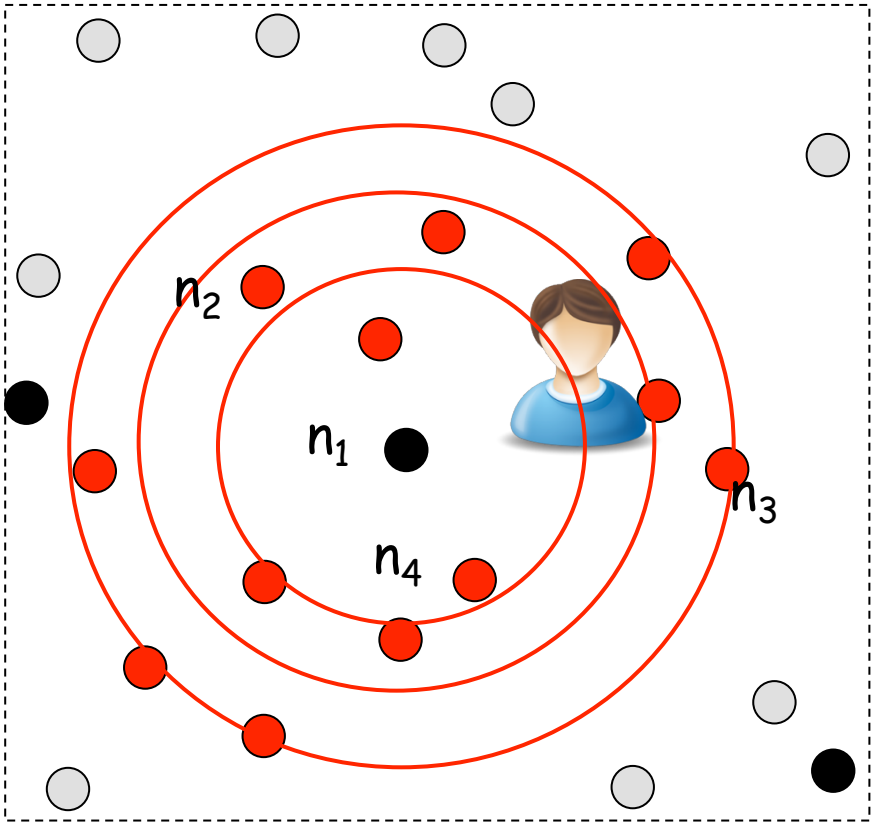
Disaster relief, Search & Rescue, Intrusion detection, …

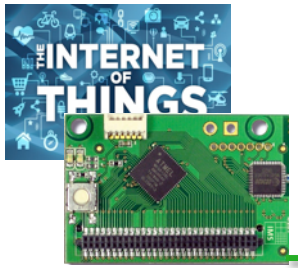
Energy vs Criticality dilemma



18720 Joules

Energy preservation is not the main objective!





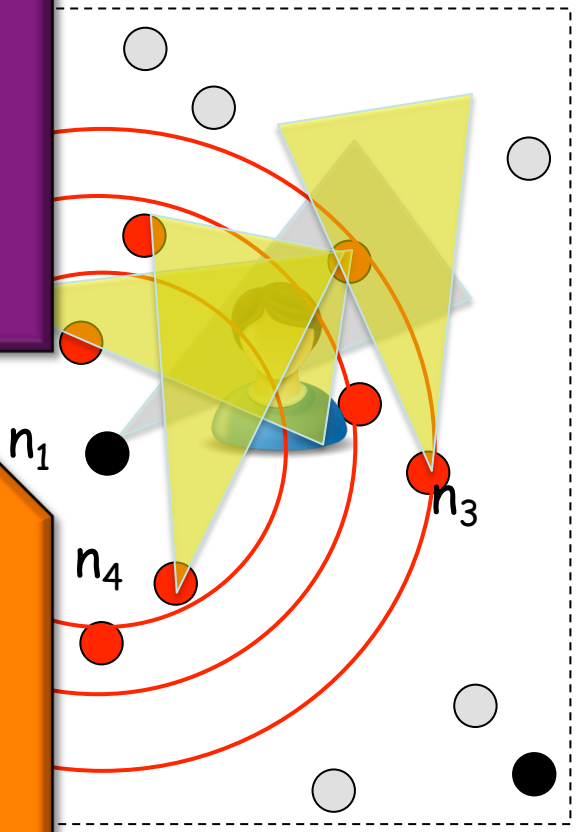
Using image sensors

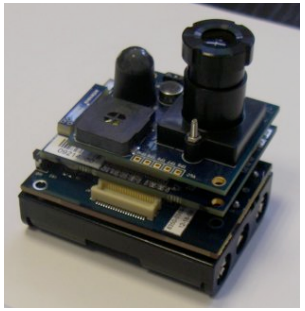
Periodically capture to detect intrusions

Send alerts to neighbors

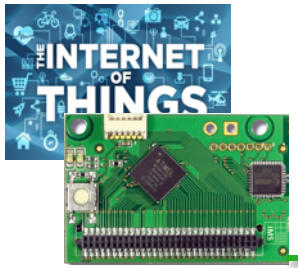
Propagate alerts to the sink

Send images to the sink





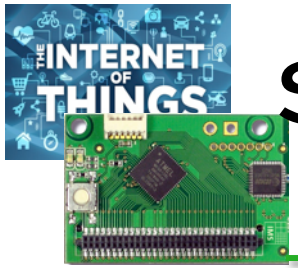
alerted node



Don't miss important events!

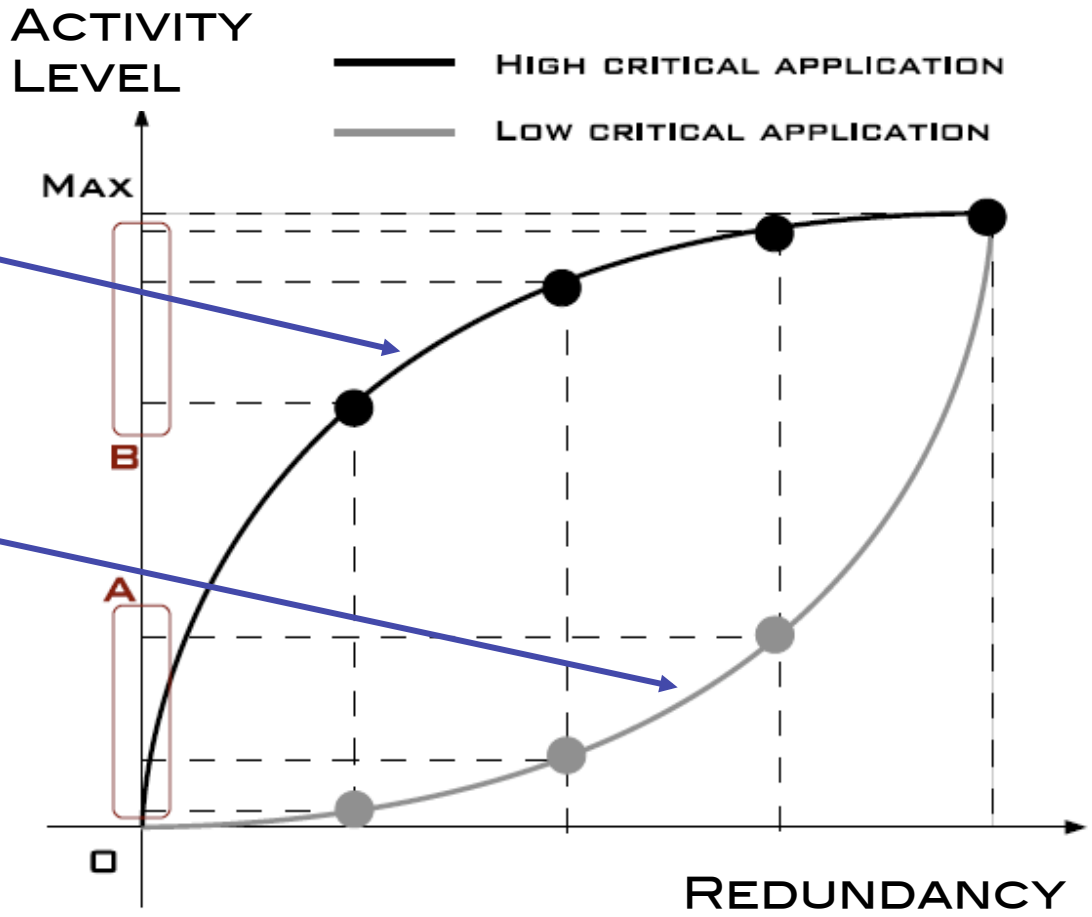
Whole understanding of the scene is wrong!!!

What is captured



Schedule activity with criticality in mind

- Link the activity to redundancy level
- High criticality
  - Convex shape
  - Most projections of X are close to the max activity
- Low criticality
  - Concave shape
  - Most projections of X are close to the min activity
- Concave and convex shapes automatically define sentry nodes in the network



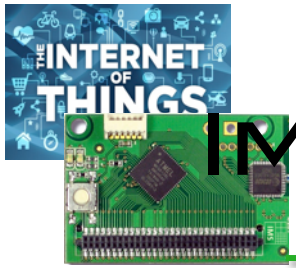
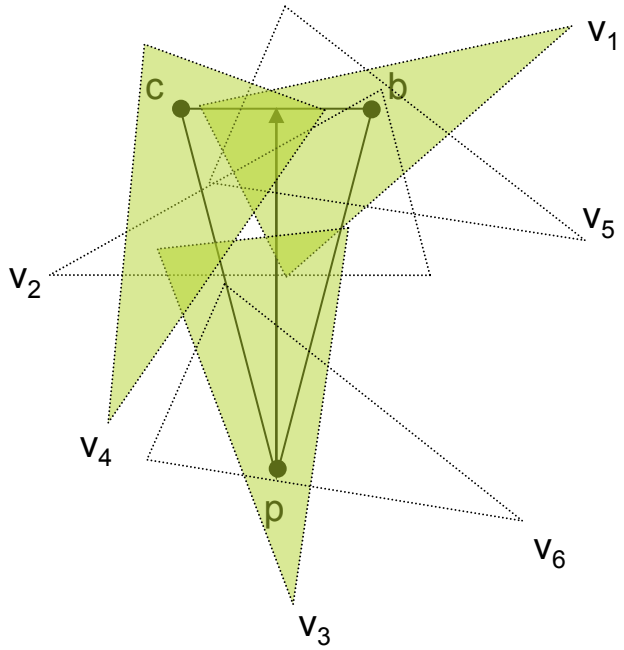
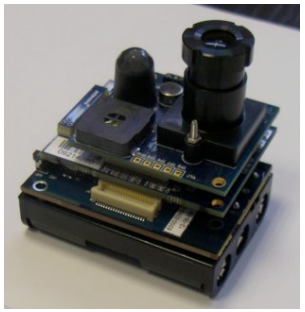


IMAGE SENSOR'S COVER SET

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





Proposed criticality model

- r^0 can vary in [0
- Behavior funct
  (BV) defines the
  capture speed
  according to r^0
- $r^0 < 0.5$
  - Concave shape

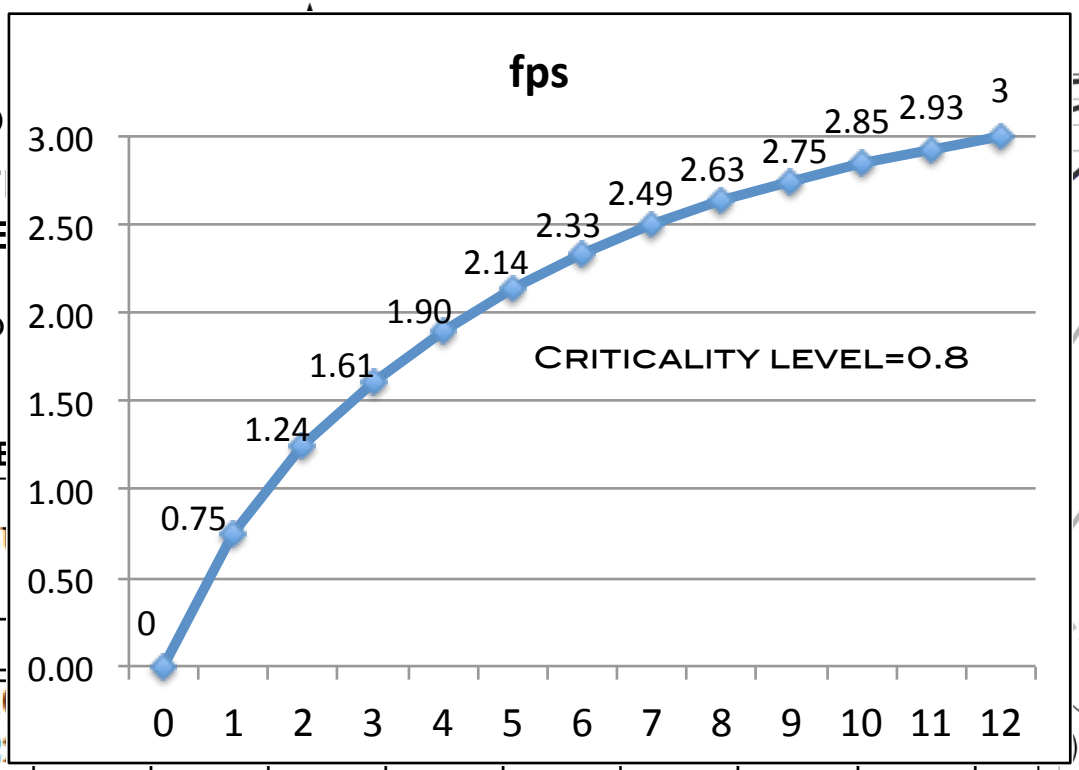
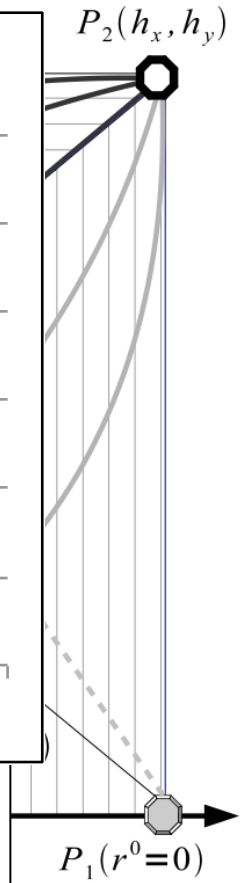
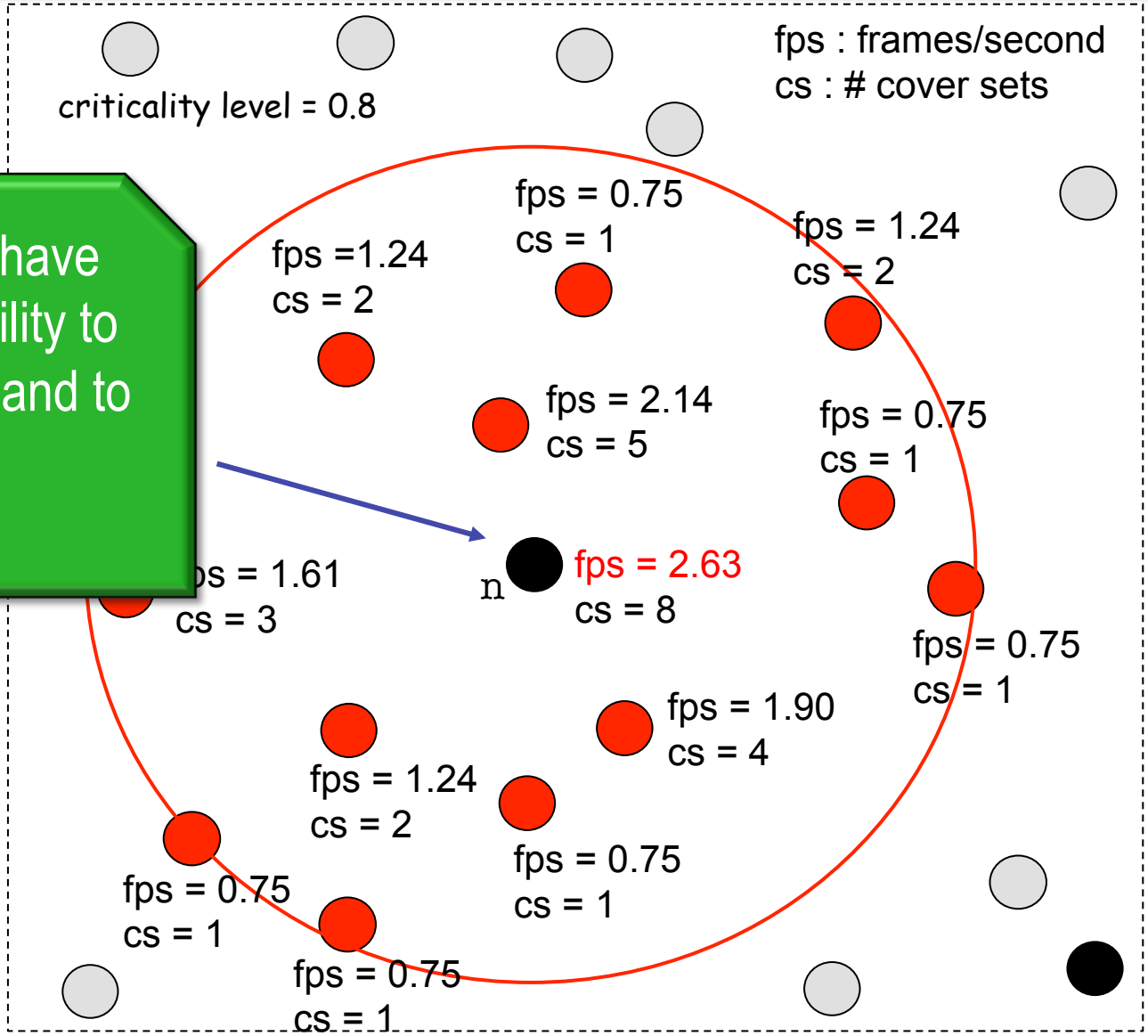


Table 1: Capt

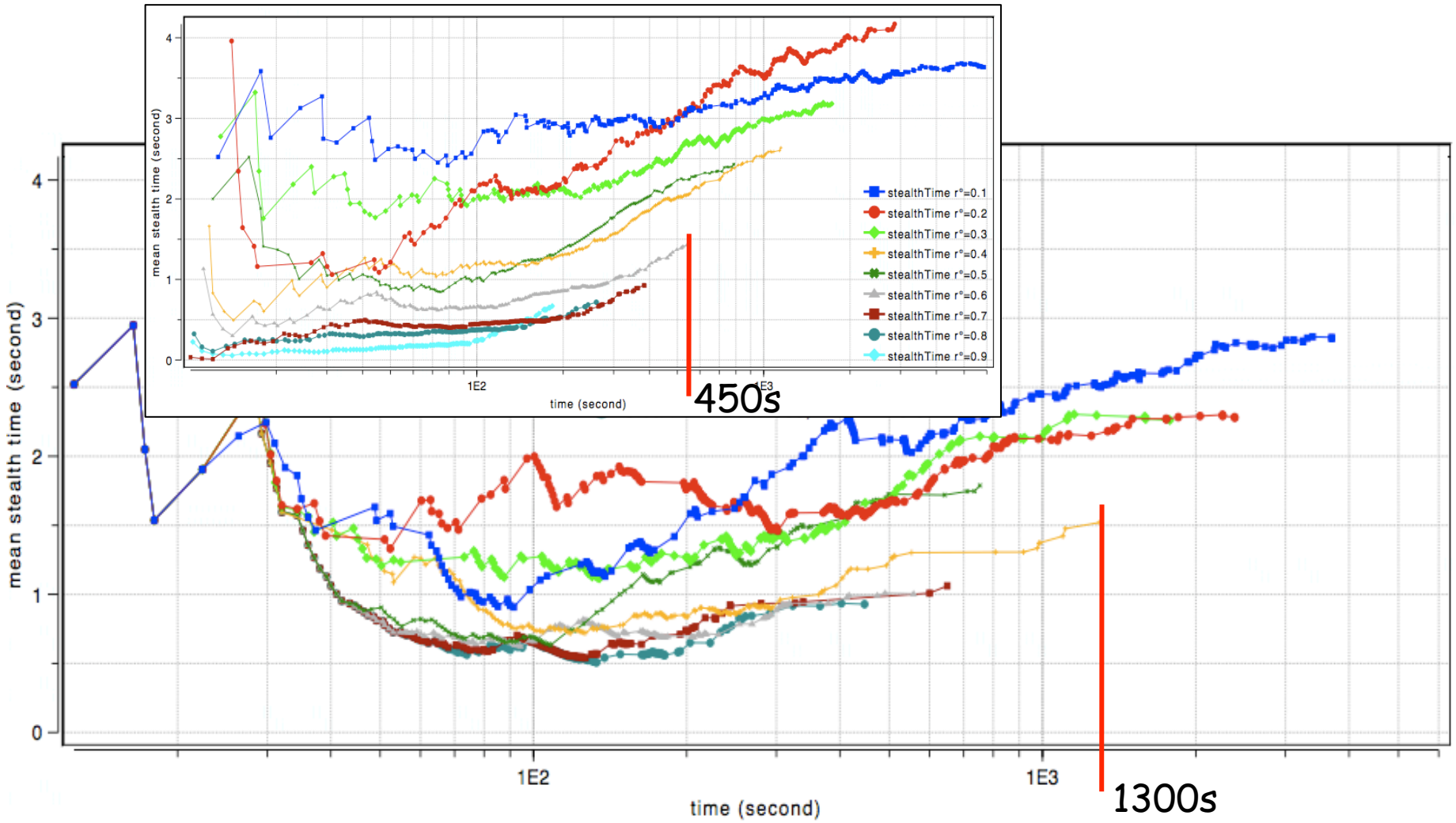
r^0	1	2	3	4								
0	0.01	0.02	0.05	0.1								
.1	0.03	0.08	0.14	0.2								
.4	0.17	0.35	0.55	0.75	0.97	1.20	1.45	1.72	2.00	2.31	2.64	3
.6	0.36	0.69	1.00	1.28	1.55	1.80	2.03	2.25	2.45	2.65	2.83	3
.8	0.75	1.24	1.61	1.90	2.14	2.33	2.49	2.63	2.75	2.85	2.93	3
1	1.48	1.95	2.25	2.46	2.62	2.74	2.83	2.90	2.95	2.98	2.99	3

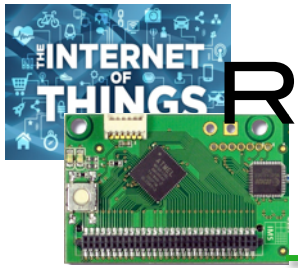


CRITICALITY-BASED ACTIVITY SCHEDULE

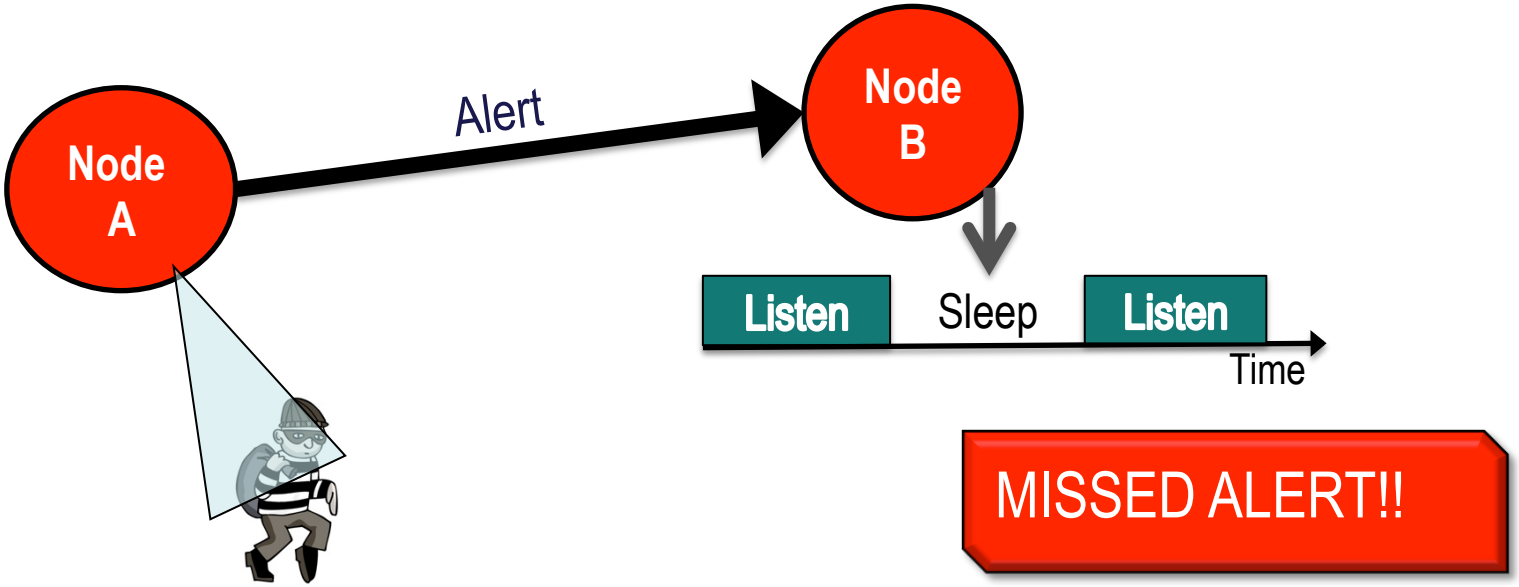


MEAN STEALTH TIME UNDER CRITICALITY-BASED SCHEDULING

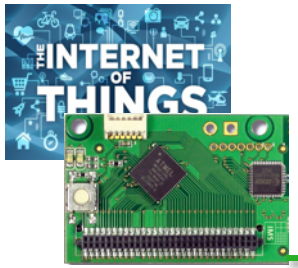




Radio/MAC duty-cycling Issues

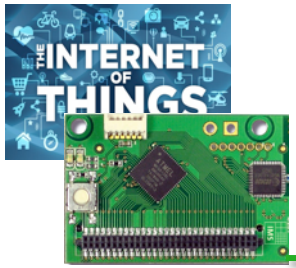


- Radio & MAC layer activities represent a large part of energy consumption

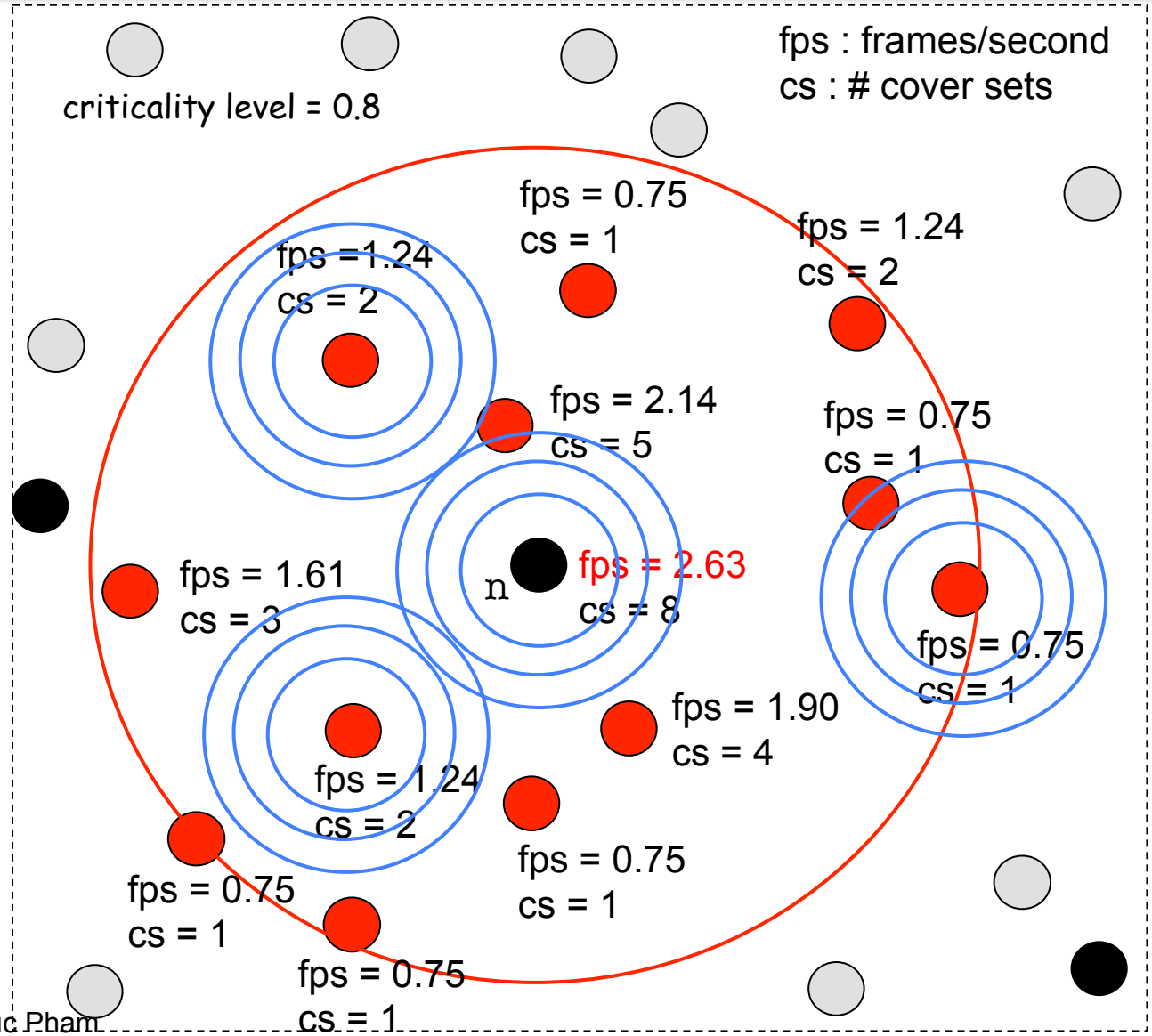


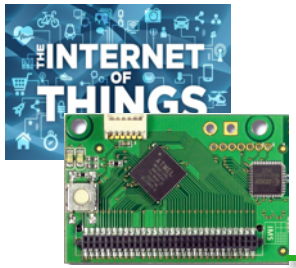
Adaptive duty-cycled MAC protocol

- Static duty-cycle MAC can not adapt to application's needs nor to surveillance's criticality
- Synchronized duty-cycle MAC approaches do not scale well
- Adaptive criticality-based MAC
  - Adapts the active period of follower nodes according to a sentry's activity
  - Take into account # of cover-set to preserve coverage constraints

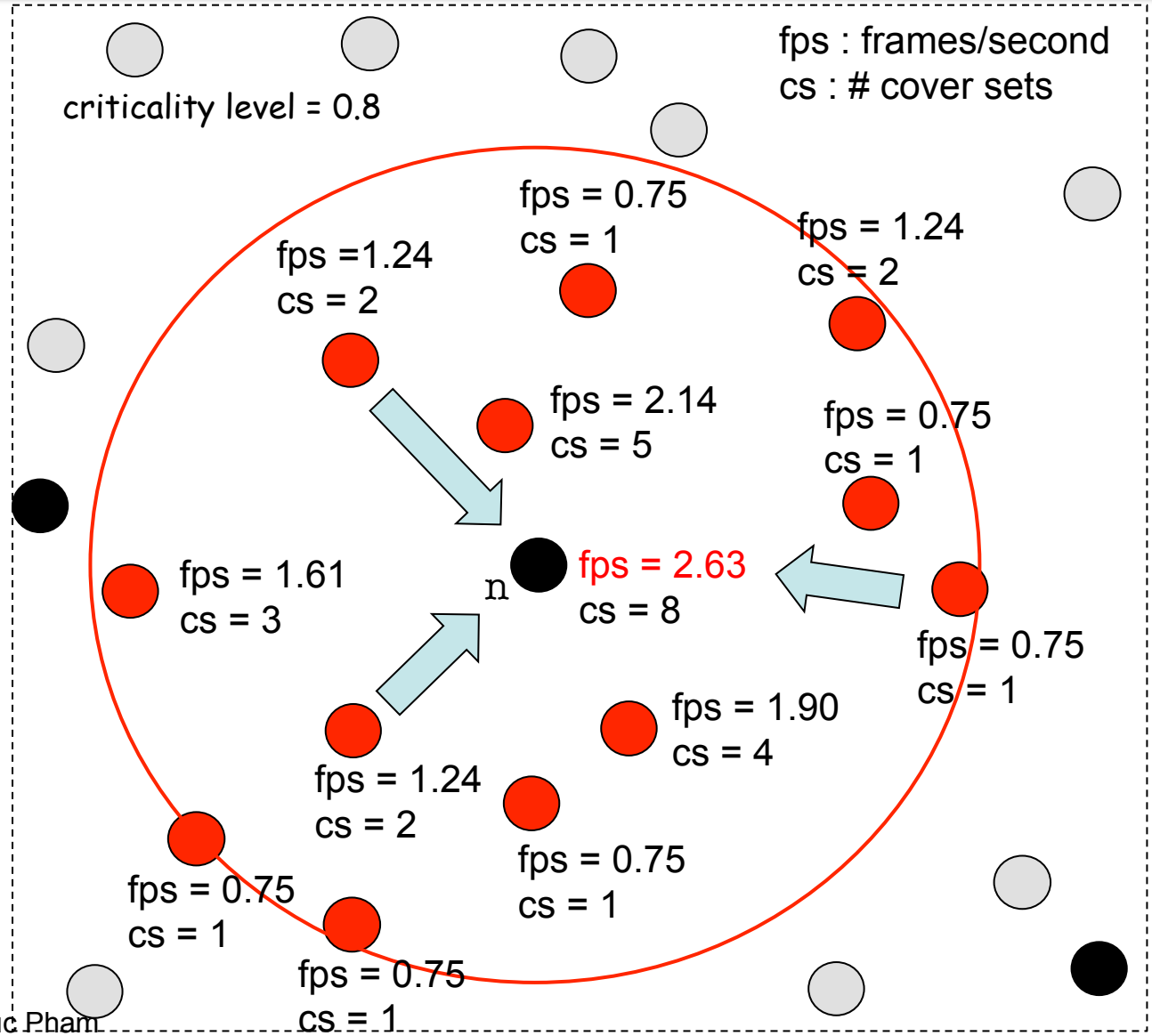


INFO BROADCAST

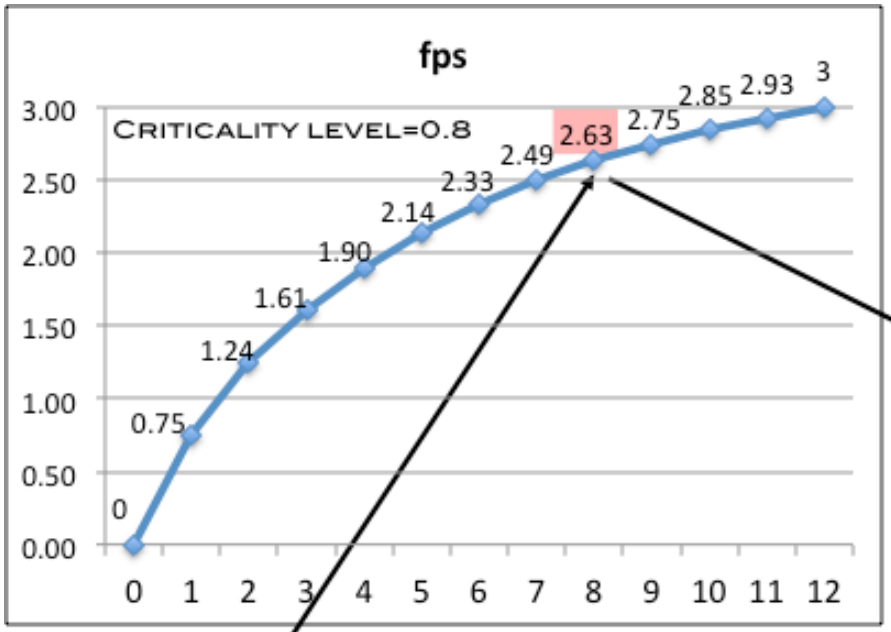




Follower-Sentry association

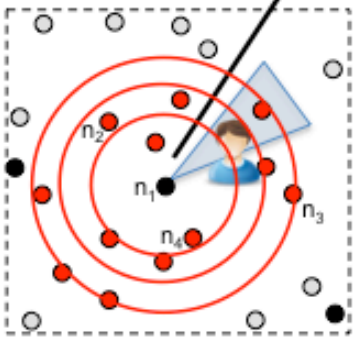


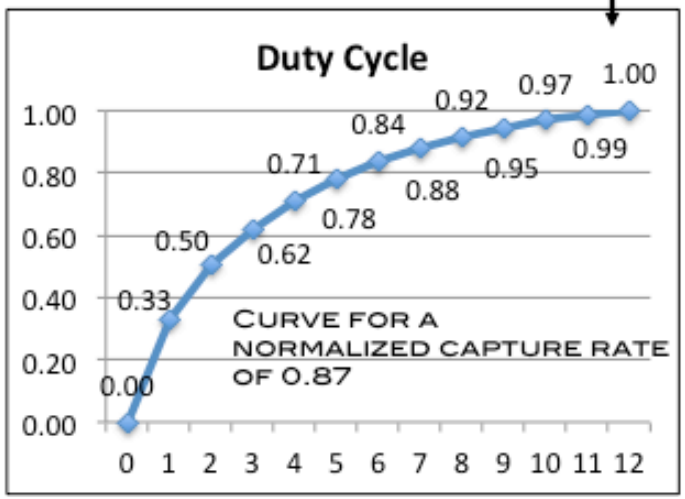
Radio/MAC Duty-cycle Computation at follower nodes



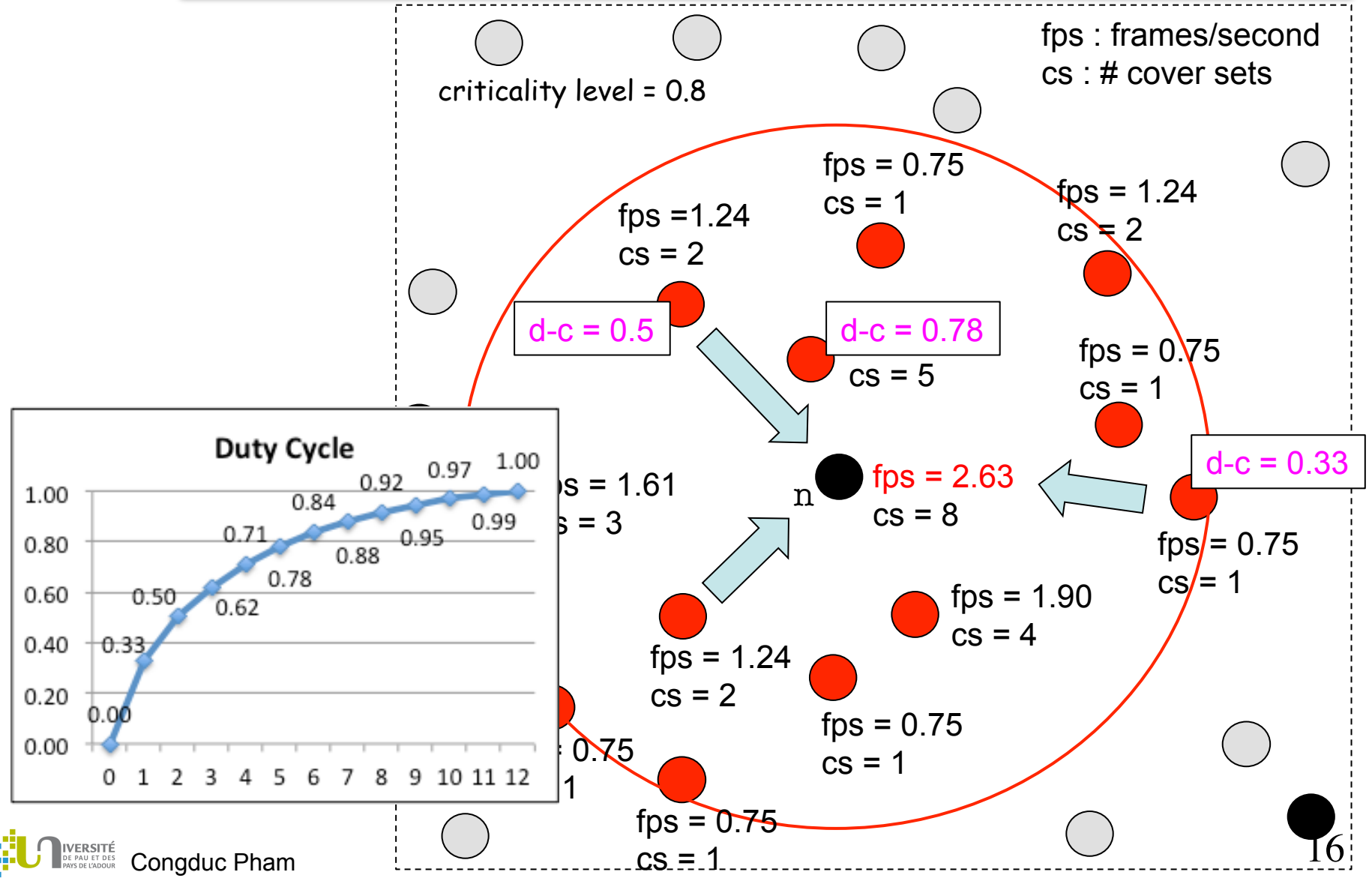
2.63/3.00=0.87

can be viewed as a new criticality level for follower nodes

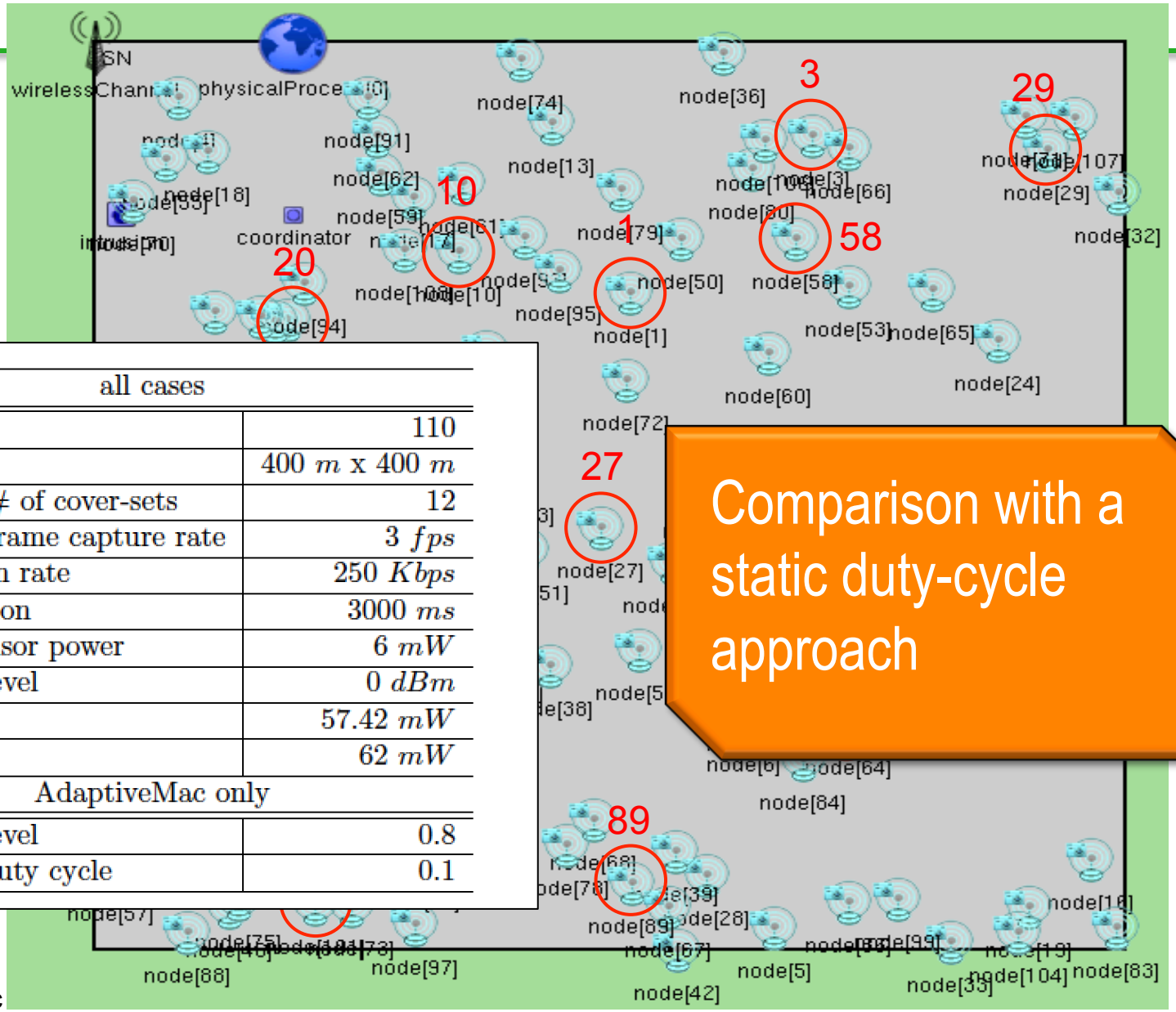




DUTY-CYCLE OF FOLLOWERS

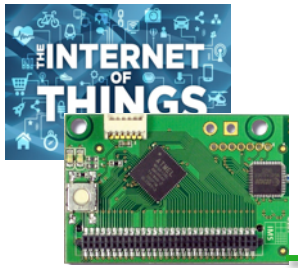


Simulation study

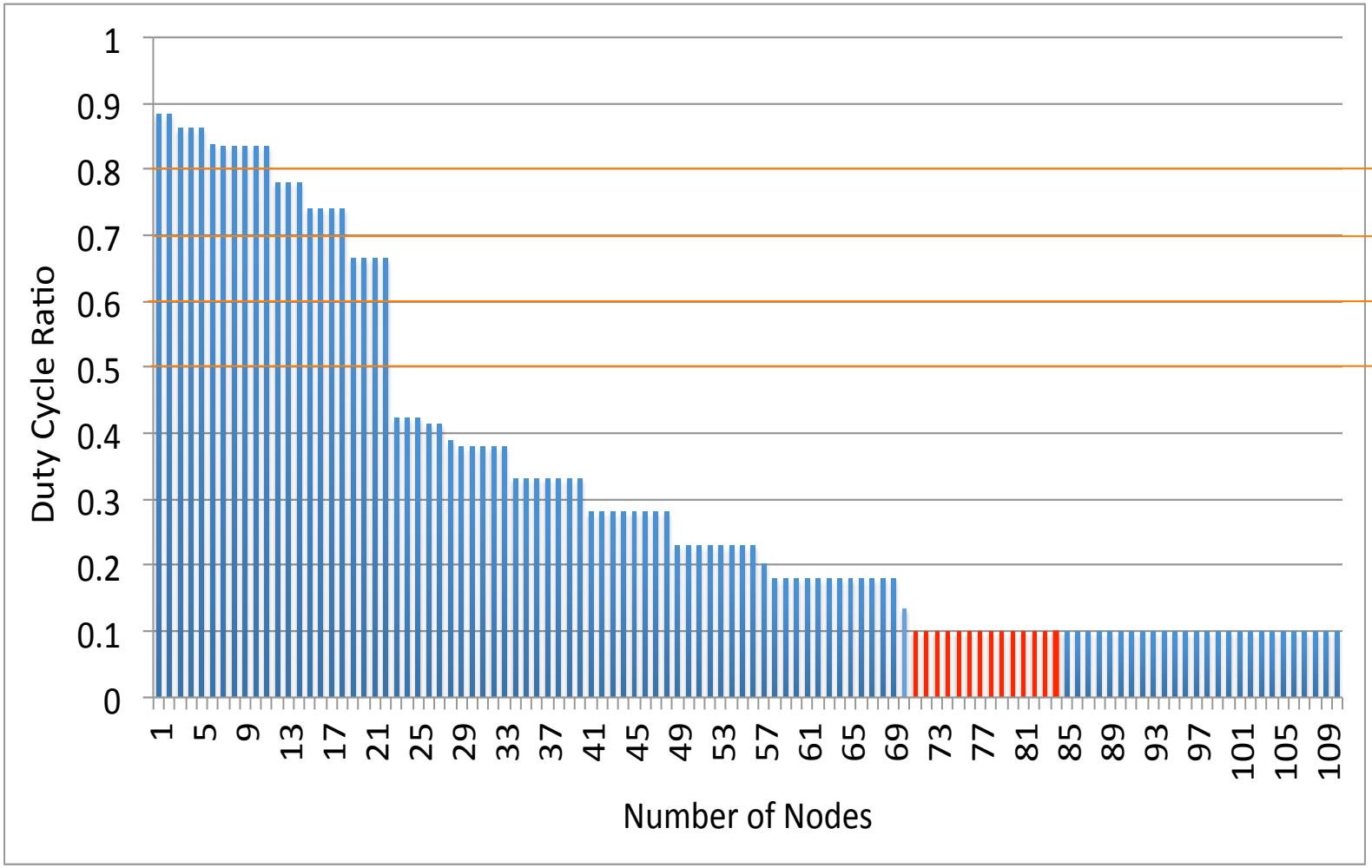


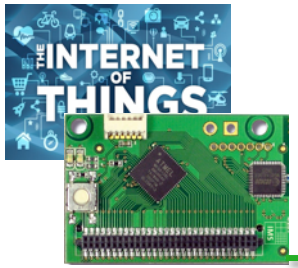
all cases	
# of nodes	110
field size	400 m x 400 m
maximum # of cover-sets	12
maximum frame capture rate	3 fps
transmission rate	250 $Kbps$
cycle duration	3000 ms
baseline sensor power	6 mW
Tx power level	0 dBm
Tx power	57.42 mW
Rx power	62 mW
AdaptiveMac only	
criticality level	0.8
minimum duty cycle	0.1

Comparison with a static duty-cycle approach

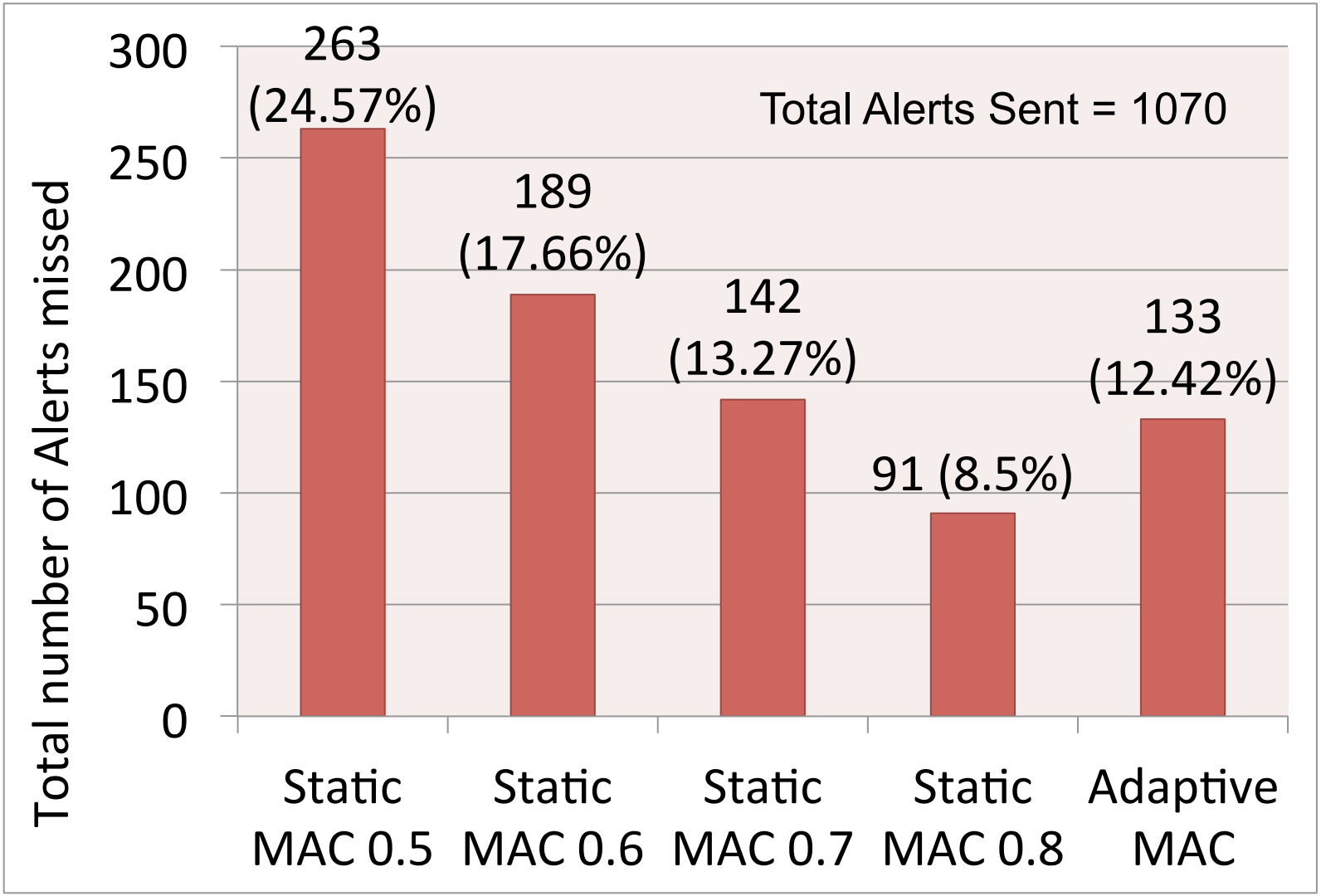


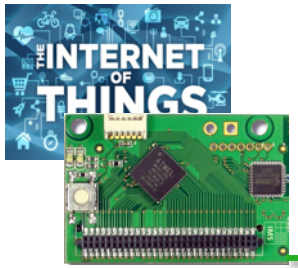
Duty-cycle length



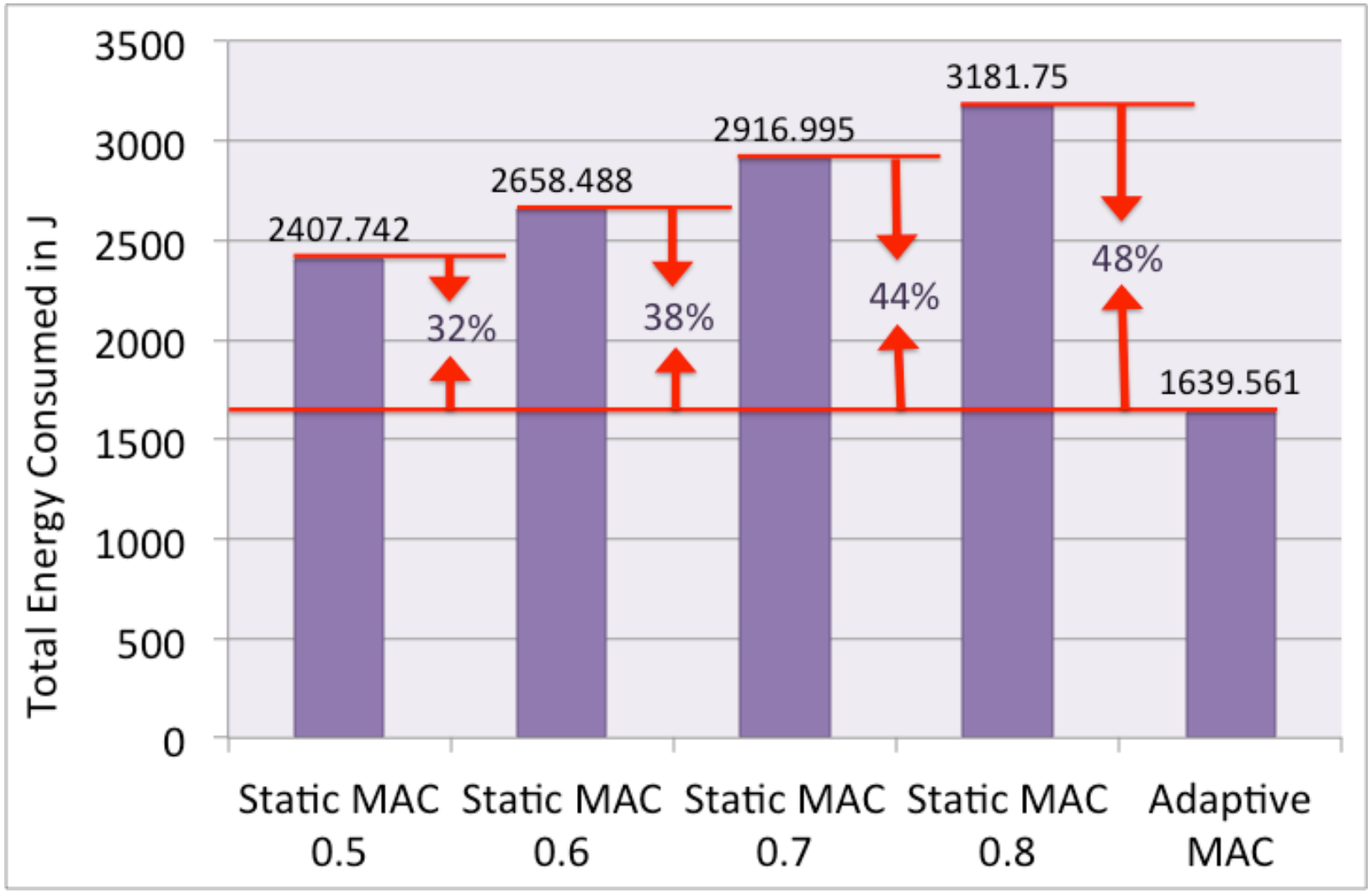


OF MISSED ALERTS

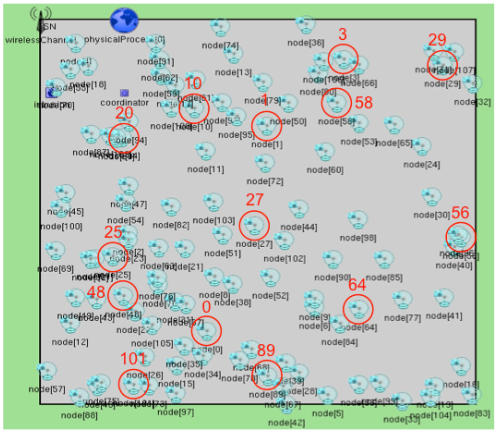




Global energy consumption

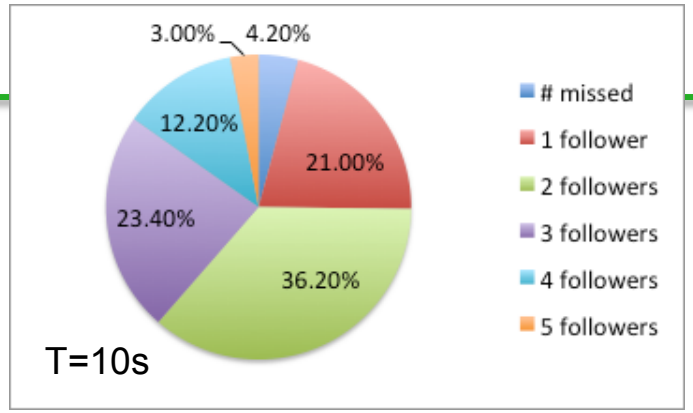


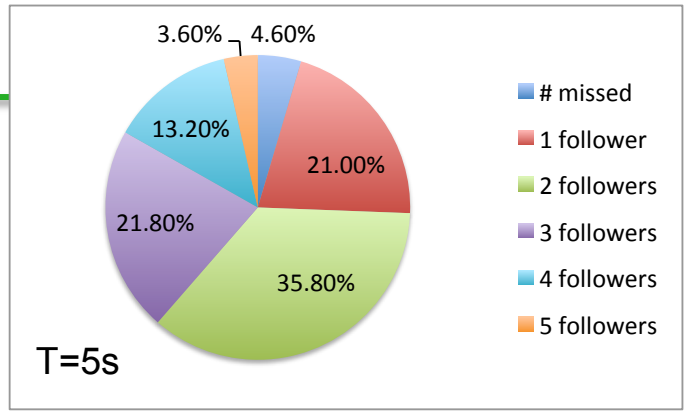
Impact of cycle length

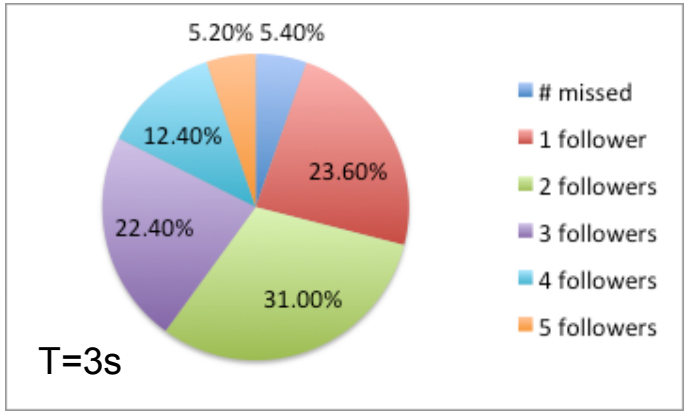


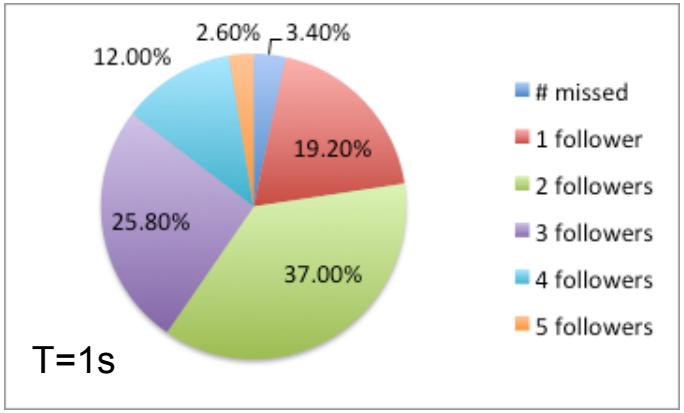
Sentry node 10

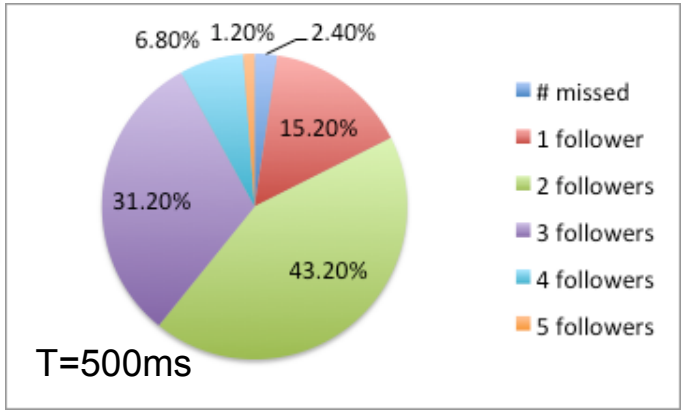
- 5 neighbors
- 5 followers

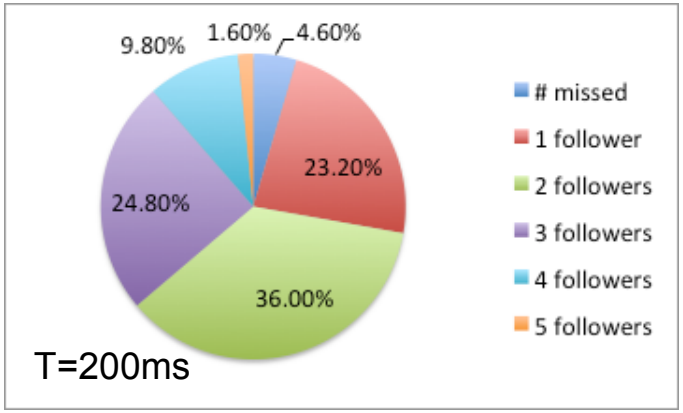




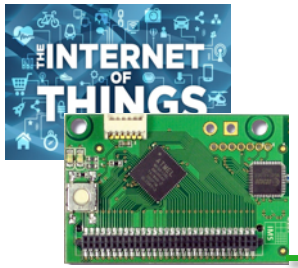






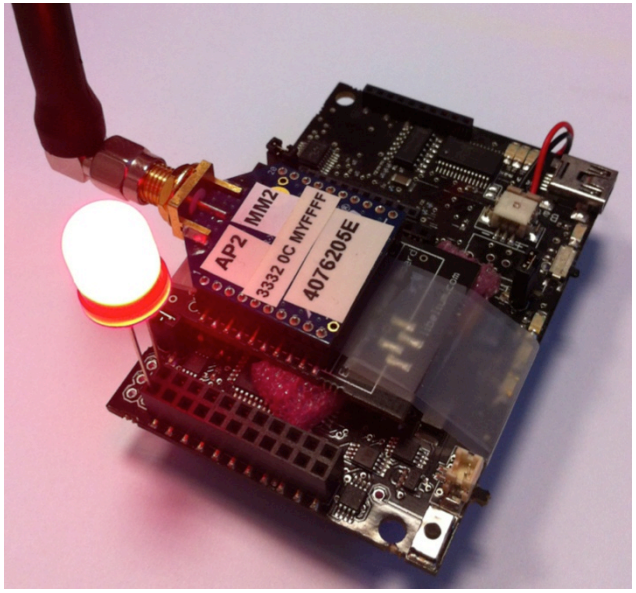


Congduc Pham

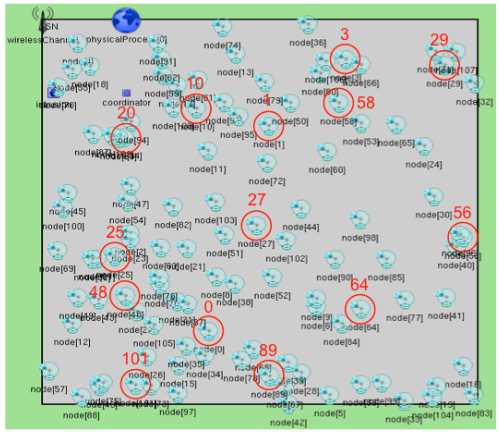


Implementation

- Libelium Waspmote with Xbee module
- Easy to completly power off the radio module
- Sentry is emulated with a Linux machine

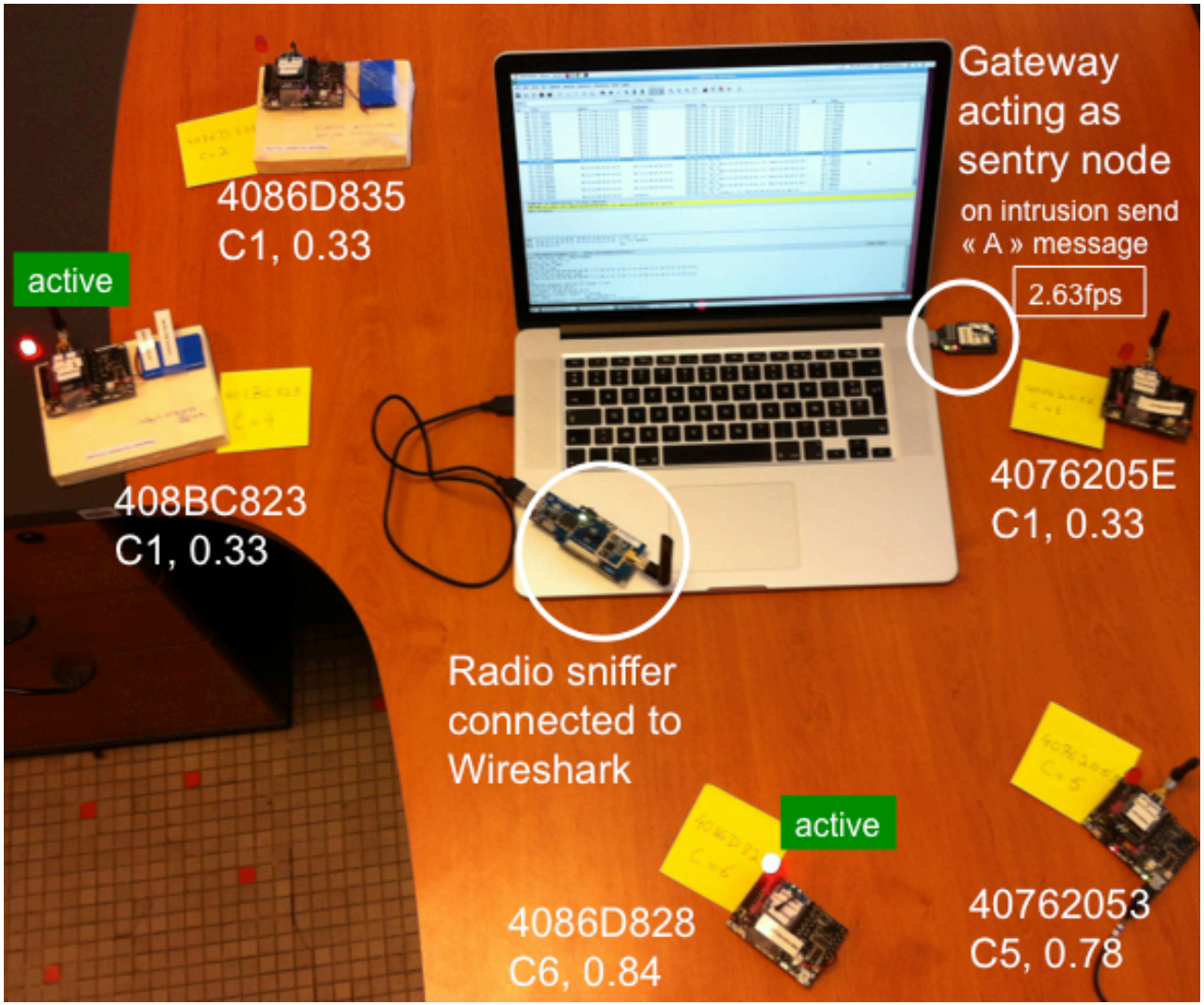


Sentry node 10 configuration

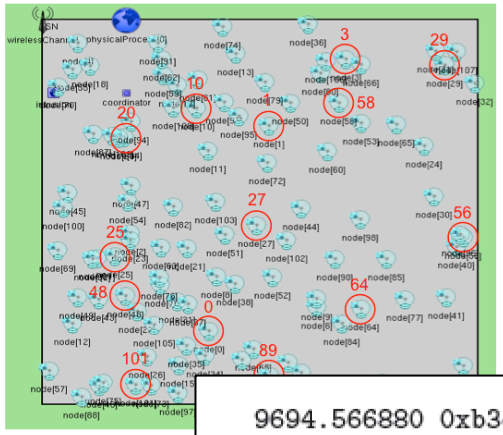


Sentry node 10

All 5 neighbors are followers



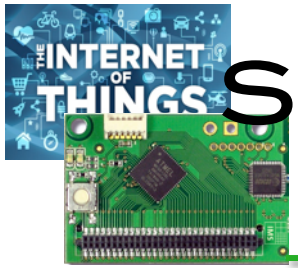
Experiments with Sentry Node 10 Data Trace



```
10 SN.node[10].Application Sending [alert]
18 SN.node[10].Application
23 SN.node[10].Application
29 SN.node[10].Application
35 SN.node[10].Application
40 SN.node[10].Application
47 SN.node[10].Application
54 SN.node[10].Application
62 SN.node[10].Application
69 SN.node[10].Application
79 SN.node[10].Application
86 SN.node[10].Application
```

```
Start time is
Mon Apr 21 15:01:07 2014
10
sleep for 10
Mon Apr 21 15:01:17 2014 : time 10 Intrusion 1 : sending alert
18
sleep for 8
Mon Apr 21 15:01:25 2014 : time 18 Intrusion 2 : sending alert
```

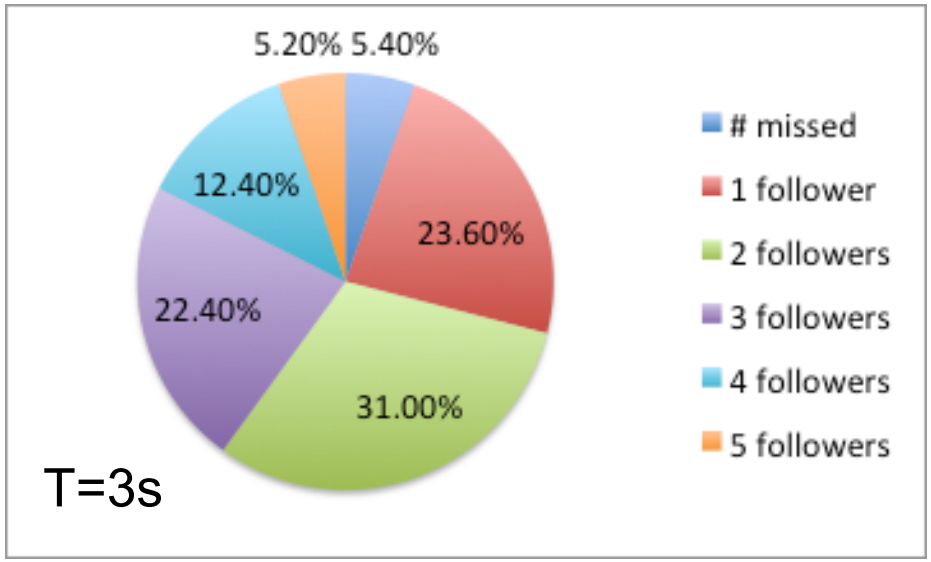
```
9694.566880 0xb3e8                  Dst: Broadcast, Src: 0xb3e8
9694.736000 00:13:a2:00:40:76:20:53 Dst: Broadcast, Src: Maxstrea_00:40:76:20:53   : sending alert
9694.862784 00:13:a2:00:40:86:d8:35 Dst: Broadcast, Src: Maxstrea_00:40:86:d8:35
9702.221312 0xb3e8                  Dst: Broadcast, Src: 0xb3e8
9702.387296 00:13:a2:00:40:86:d8:35 Dst: Broadcast, Src: Maxstrea_00:40:86:d8:35   : sending alert
9702.388820 00:13:a2:00:40:86:d8:28 Dst: Broadcast, Src: Maxstrea_00:40:86:d8:28
9702.390560 00:13:a2:00:40:76:20:5e Dst: Broadcast, Src: Maxstrea_00:40:76:20:5e   : sending alert
9702.393216 00:13:a2:00:40:8b:c8:23 Dst: Broadcast, Src: Maxstrea_00:40:8b:c8:23
9707.064864 0xb3e8                  Dst: Broadcast, Src: 0xb3e8
9707.230816 00:13:a2:00:40:8b:c8:23 Dst: Broadcast, Src: Maxstrea_00:40:8b:c8:23   : sending alert
9707.630624 00:13:a2:00:40:86:d8:28 Dst: Broadcast, Src: Maxstrea_00:40:86:d8:28
9713.010560 0xb3e8                  Dst: Broadcast, Src: 0xb3e8
9713.097024 00:13:a2:00:40:76:20:53 Dst: Broadcast, Src: Maxstrea_00:40:76:20:53   : sending alert
9713.099616 00:13:a2:00:40:8b:c8:23 Dst: Broadcast, Src: Maxstrea_00:40:8b:c8:23
9713.176720 00:13:a2:00:40:86:d8:28 Dst: Broadcast, Src: Maxstrea_00:40:86:d8:28
...
9799.369728 0xb3e8                  Dst: Broadcast, Src: 0xb3e8, Bad FCS
9812.351552 0xb3e8                  Dst: Broadcast, Src: 0xb3e8, Bad FCS
...
```



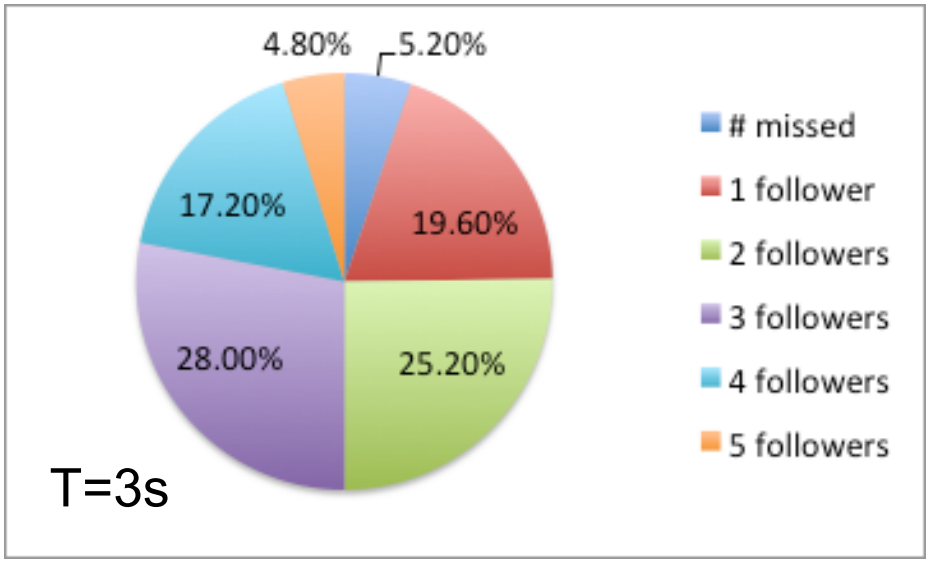
Simulation & Experiment comparison

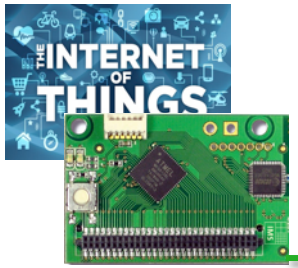
- Cycle length is set to 3000ms

Simulation



Experimentation





Conclusions

- WSN's natural application is surveillance but…
- … using WSN technology for mission-critical applications is far from being mature!
- Need to take the application's criticality into account when designing control mechanisms and protocols
- We proposed
  - A criticality-based activity scheduling for image sensors
  - An adaptive criticality-based MAC protocol to provide duty-cycle support
- Results
  - Activity schedule: increase lifetime (300%) while maintaining detection quality
  - MAC: Compared with a static duty-cycle approach, our protocol reduces the number of missed alerts and the energy consumption (by 44%) while maintaining the same level of responsiveness