Overcoming the Deficiencies of Collaborative Detection of Spatially-correlated Events in WSN

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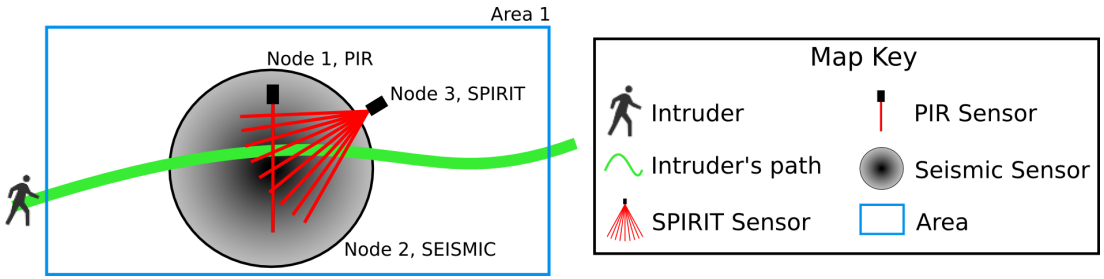
Outline



Detecting spatio-temporally correlated events

An architecture can be evaluated with the following metrics:

- the detection latency
- the wireless network lifespan

Detection constraints

- local latency <= 1 second
- overall latency <= 10 seconds
- network lifespan of several months

Detection latency

Detection latency comes from:

- the sensors' polling frequency
- the local correlation time
- the network latency
- the network-wide correlation time

A node's power consumption

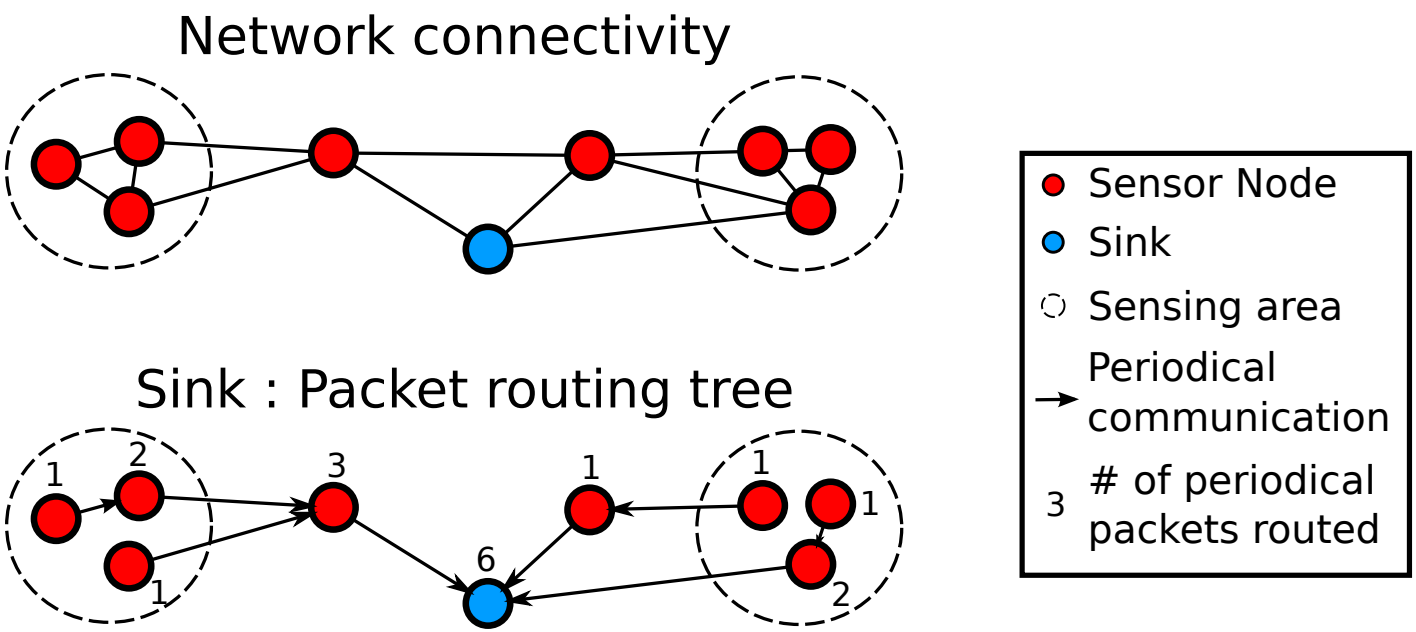
A node's power consumption depends on:

- the microcontroler's architecture and its duty cycle (constant)
- the radio and its duty cycle (constant)
- the attached sensors' power consumption (constant)
- the number of messages sent and received (variable)

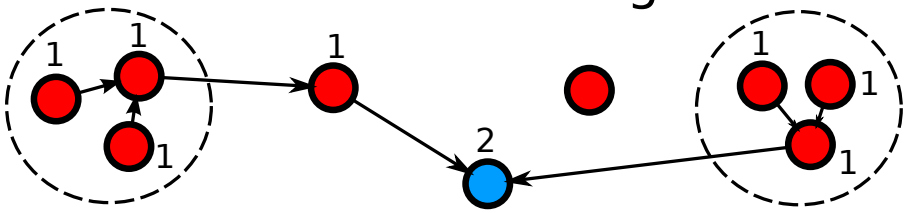
Network lifespan

The lifespan of the network is limited by:

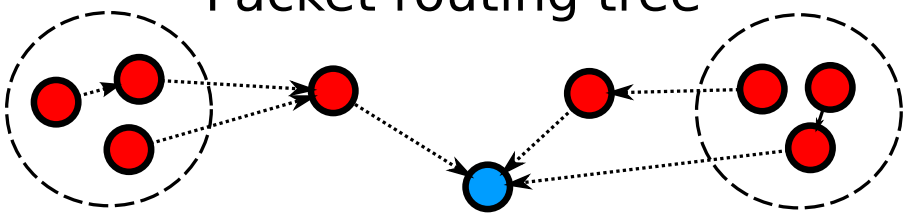
- the average power consumption
- the lifespan of each nodes keeping the network connected



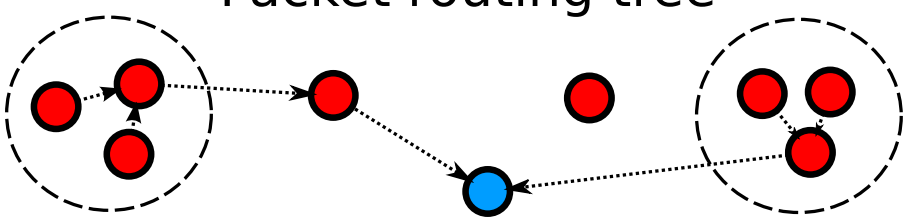
Cluster aggregation :
Packet routing tree

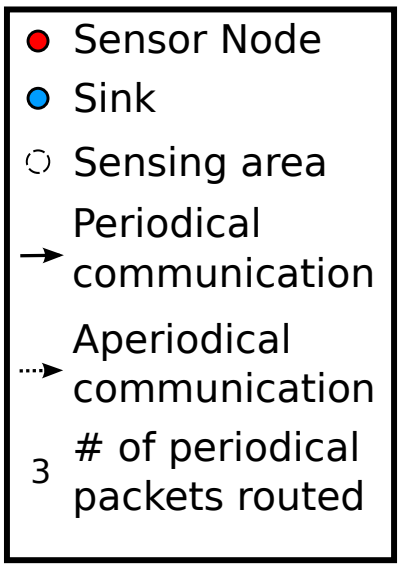


Local Data correlation :
Packet routing tree



Collaborative detection :
Packet routing tree





Network type	Multi hop	Shortens communications	Local data processing	User	Heterogeneous correlation	Autonomous
Sink [1]	X			External		
Cluster aggregation [2]	X	X		External		
Local data aggregation [3]	X		X	External		
Collaborative detection [4]	X	X	X	External		
Diaforus [5]	X	X	X	Internal & External	X	X

Table: Comparaison of usual wireless sensor networks with Diaforus's goals

Outline

Correlation : goals

- support heterogeneous & redundant sensors
- lower the message count
- shorten the communications' average length
- be as autonomous as possible

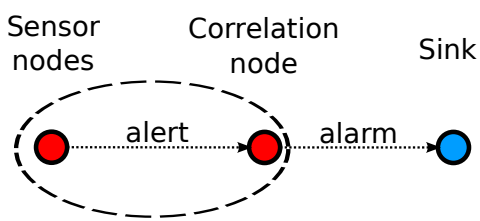
Constraints

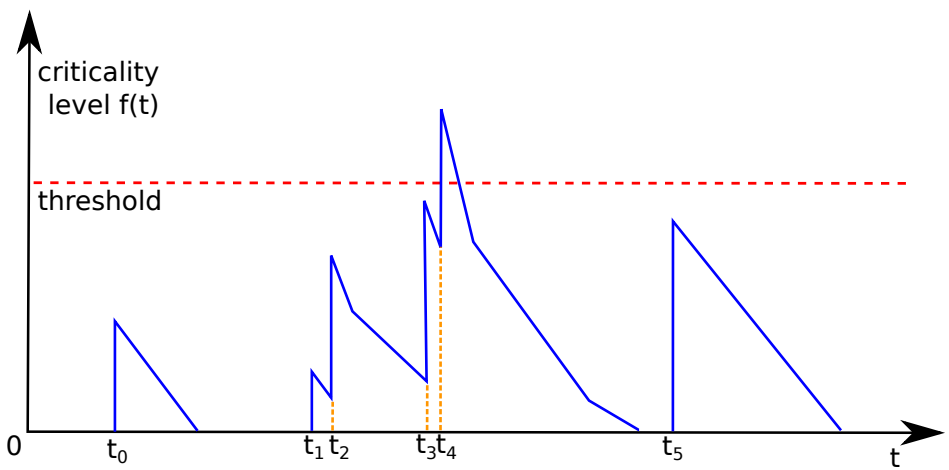
- sensors are ill-calibrated and noisy
- sensors may not be reachable at all time

Proposal

Our proposal is building on state-of-the-art collaborative detection

- split data processing in two parts:
  - local correlation
  - area-wide correlation
- normalize the sensors' values locally to abstract sensors
- increase the area criticality level on a local detection
- decrease events' contributions to the criticality level with time





Logging : motivation

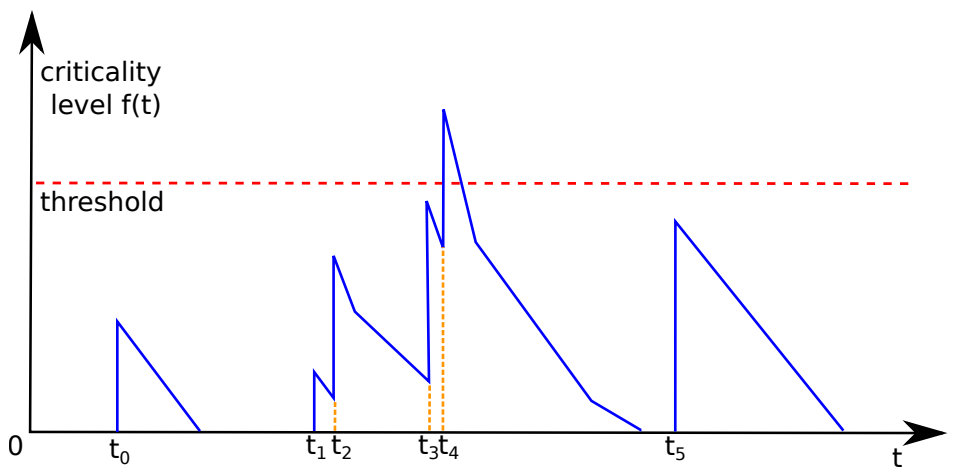
- auditing the system is difficult because it is now distributed
- network operators may not be reachable at all time

Constraint

- sensor nodes are tightly memory-constrained

Proposal

- store events in the correlation node:
  - local timestamp
  - a confidence level (alarm level)
  - list of sensors detecting this event
  - relative contribution of each sensor
- keep the most important events:
  - confidence level & time spent as the local maximum
  - age & events expiration time
- export this database using a REST protocol (CoAP)



Reputation : motivation

- detect faulty or ill-positioned sensors

Constraint

- sensor nodes are tightly memory-constrained

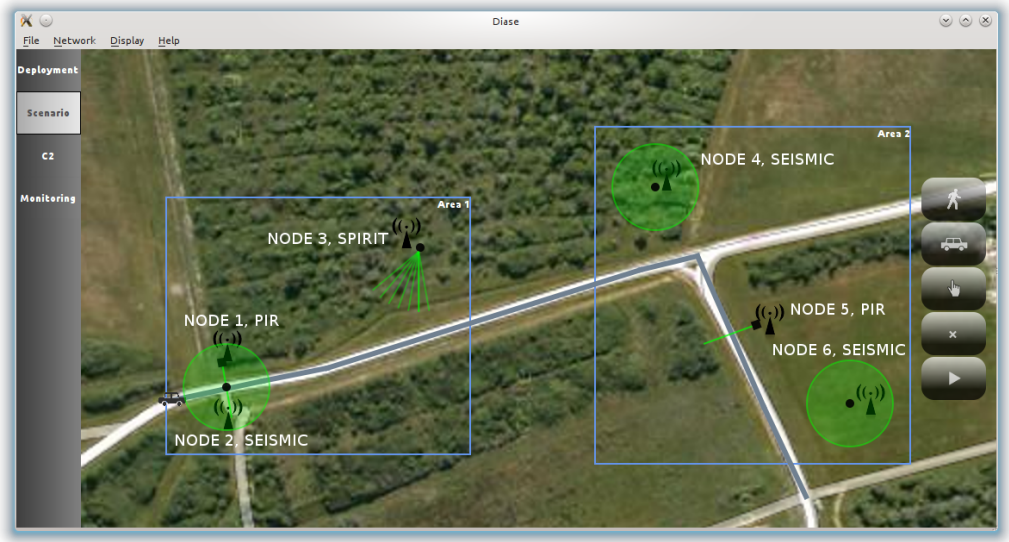
Proposal

- use the offline logging data to compute reputation
- rate sensors according to false-positive and false-negative:
  - false-positive: $\frac{uncorrelated\ \ alerts}{alarms}$
  - false-negative: $\frac{correlated\ \ alerts}{alarms}$
- rating goes from 1 (perfect) to 0
- an event can be sent when a sensor's reputation is low
- this event can be used inside or outside the network

Outline

Evaluation

- Simulation : using the scenario mode of Diase
- Real-life deployment : Thales military field



WSN type	readings	short-distance	long-distance
Sink	5400	0 (0%)	5400 (100%)
Cluster aggregation	5400	3600 (67%)	1800 (33%)
Local detection	5400	0 (0%)	540 (10%)
Collaborative detection	5400	$\leq$ 540 (10%)	$<$ 180 (3.33%)

Table: Comparing WSN data management on a 3-nodes area with a sensor noise probability (p=0.1, f=1Hz)

Correlation	readings	short-distance	long-distance	$\frac{long}{short}$ ratio
c=10s	5400	545 (10%)	8 (0.15%)	1.5%
c=90s	5400	525 (9.7%)	40 (0.74%)	7.7%
c=180s	5400	520 (9.6%)	56 (1.03%)	10.7%

Table: Message count in DIAFORUS with noisy sensors (f=1Hz, p=0.1) and a correlation time c. Experiment time of 30 minutes.

Sensor noise	readings	short-distance	long-distance
p=0	5400	0 (0%)	0 (0%)
p=0.002	5400	11 (0.2%)	0 (0%)
p=0.02	5400	94 (1.7%)	0 (0%)
p=0.1	5400	545 (10%)	56 (1.03%)
p=1	5400	5400 (100%)	210 (3.89%)

Table: Message count in DIAFORUS with noisy sensors (f=1Hz, p) and a correlation time of 180s. Experiment time of 30 minutes.

Reputation evaluation

2 scenarios:

- validation (non-noisy sensors)
- noisy sensors (no intrusions)

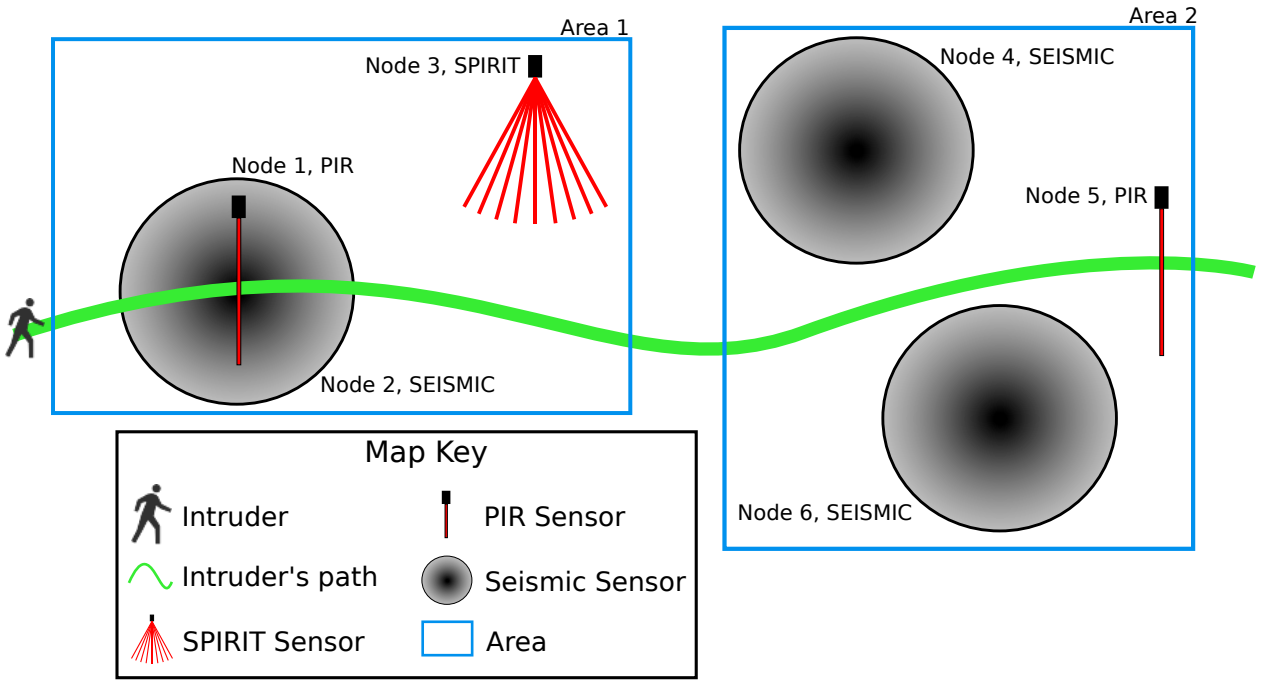


Figure: Scenario validating the reputation. 2 areas, 6 sensors.

Node ID	False positive reputation	False negative reputation
1 & 2	1 (18/18)	1 (283/283)
3	NaN (0/0)	0 (0/283)
4 & 6	NaN (0/0)	NaN (0/0)
5	0 (0/9)	NaN (0/0)

Table: Results of the validation experiment

Node ID	False positive reputation	False negative reputation
1	0.34 (57/168)	1 (119/119)
2	0.34 (57/167)	1 (119/119)
3	0.34 (57/169)	1 (119/119)

Table: Reputation of noisy sensors (p=0.1, f=1Hz) after 30 minutes and correlation time of 20 seconds

Outline

Conclusion

- we enhanced state of the art collaborative networks by abstracting sensor types
- we achieved a dramatic decrease in message counts
- we help the administrators of the system by providing logs and fitness score for sensors
- we enhanced collaborative autonomy by allowing the network to react automatically to detected events
- we demonstrated the system both in simulation and on a military field

ANR DIAFORUS

DIAFORUS is a national research project whose goals are:

- create a framework for collaborative WSNs
- correlate redundant and heterogeneous sensors
- diminish the number and the average length of communications to save power
- demonstrate with an intrusion-detection scenario

The project is carried out by Cornonis, LaBRI, Thales communications, Telecom Paritech