Cooperative Detection in Cognitive Networks to Interference Control in Licensed Systems

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Outline

Motivation

- Trend of convergence networks and services in telecommunications
- Radio frequency spectrum is not fully utilized (not all the time)
- Extensive use of wireless networks (mainly the IEEE 802.11x)
- Interest in the use of a single terminal capable of accessing these networks

Cognitive Radio

Considerations

Problems in the use of cognitive radio in *Cognitive Radio Wireless Network* (CRWN):

- Dynamic choice of operational parameters
- Network management, the available bandwidth and individual consumption
- Interoperability between technologies (MAC / PHY layers)
- Detection of legacy devices
- Interference between participants
- Some solutions are being developed for the IEEE 802.22 standard (analog TV band)

Proposal

Cooperative detection of licensed (primary) users in the frequency range where occurs opportunistic access, using a secondary network with nodes capable of performing two functions:

- Operational Function $\rightarrow$ network communication;
- Sensory Function $\rightarrow$ cooperatively makes the detection of primary transmissions and get an estimate of its distance and the angle of arrival of the signal detected.

Aiming...

Establishment of a power transmission control algorithm in secondary network (operational nodes) that considers the limit of interference tolerated by the primary network.

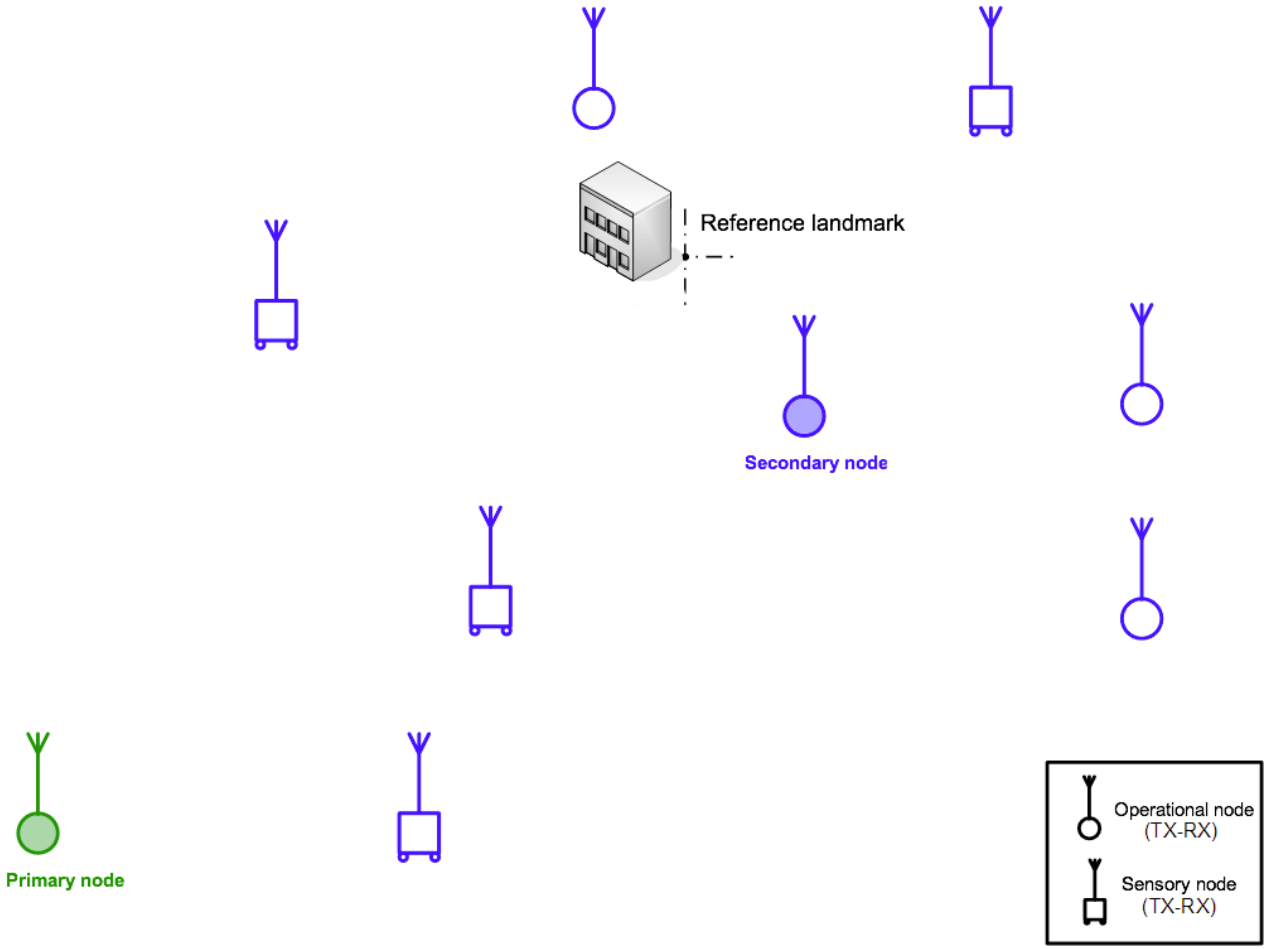


Figure: Two *ad hoc* networks: **primary** and **secondary**. Cooperation using the sensory and operational functions. Both networks have TX-RX nodes.

Proposal

Some Problems:

- Additional operations required:
  - Positioning in the secondary network operational area;
  - Detection of the transmission (high sensitivity in RX);
  - Location of the primary transmitter.
- Overload traffic because of the control messages.

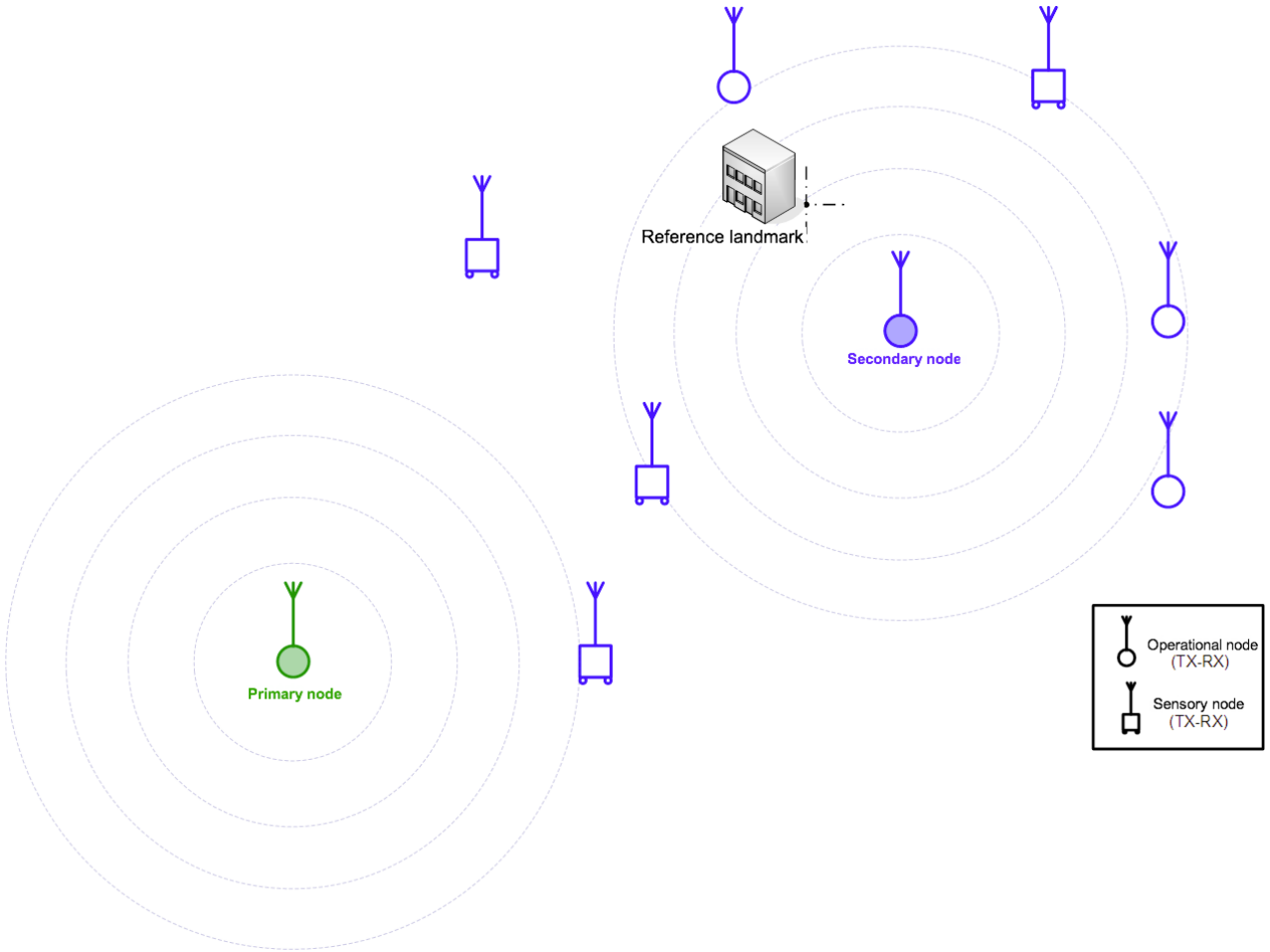


Figure: **Secondary** and **primary** networks begins to work.

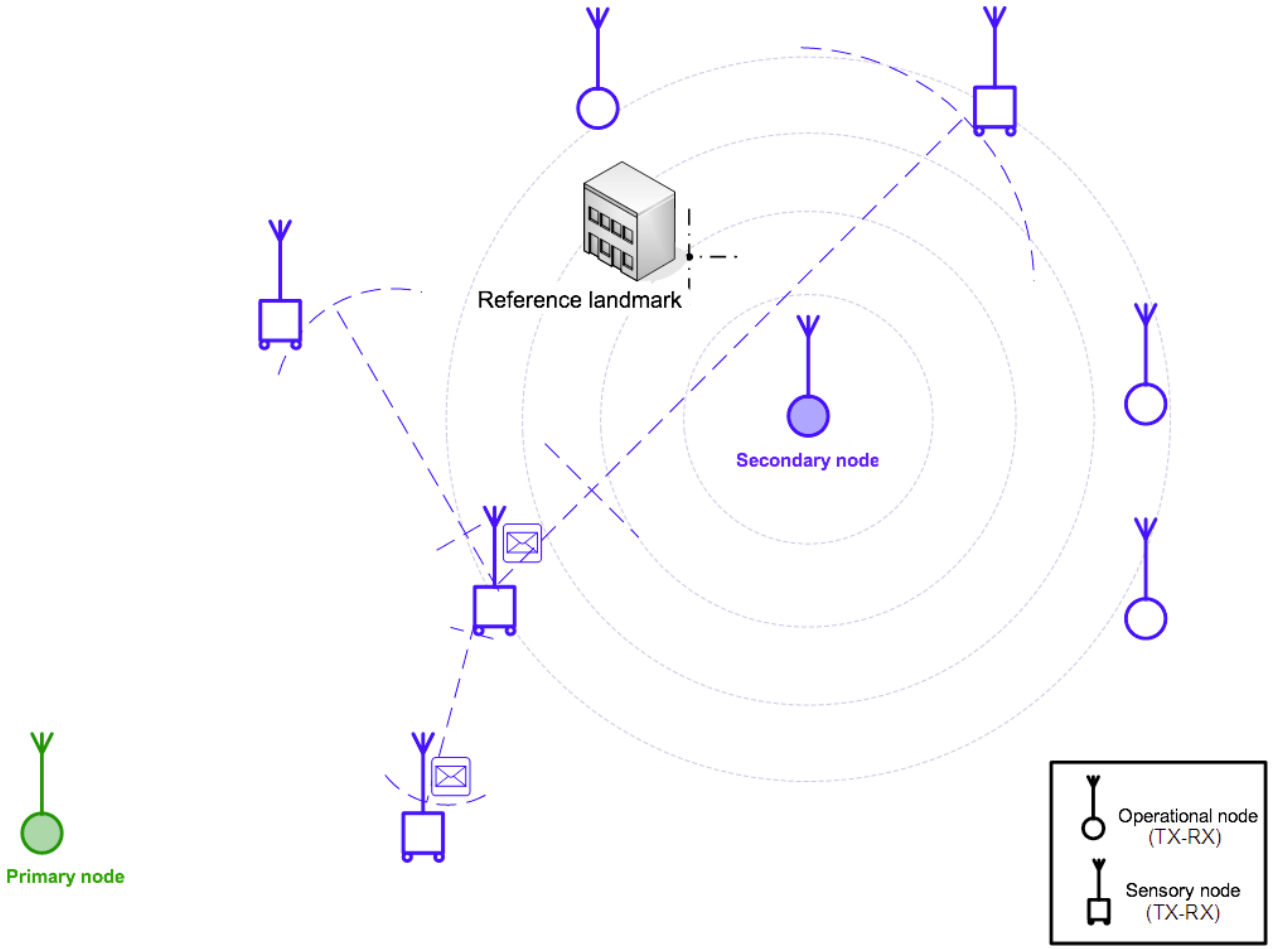


Figure: Sensory node positioned in the area detects the *secondary node* transmission.

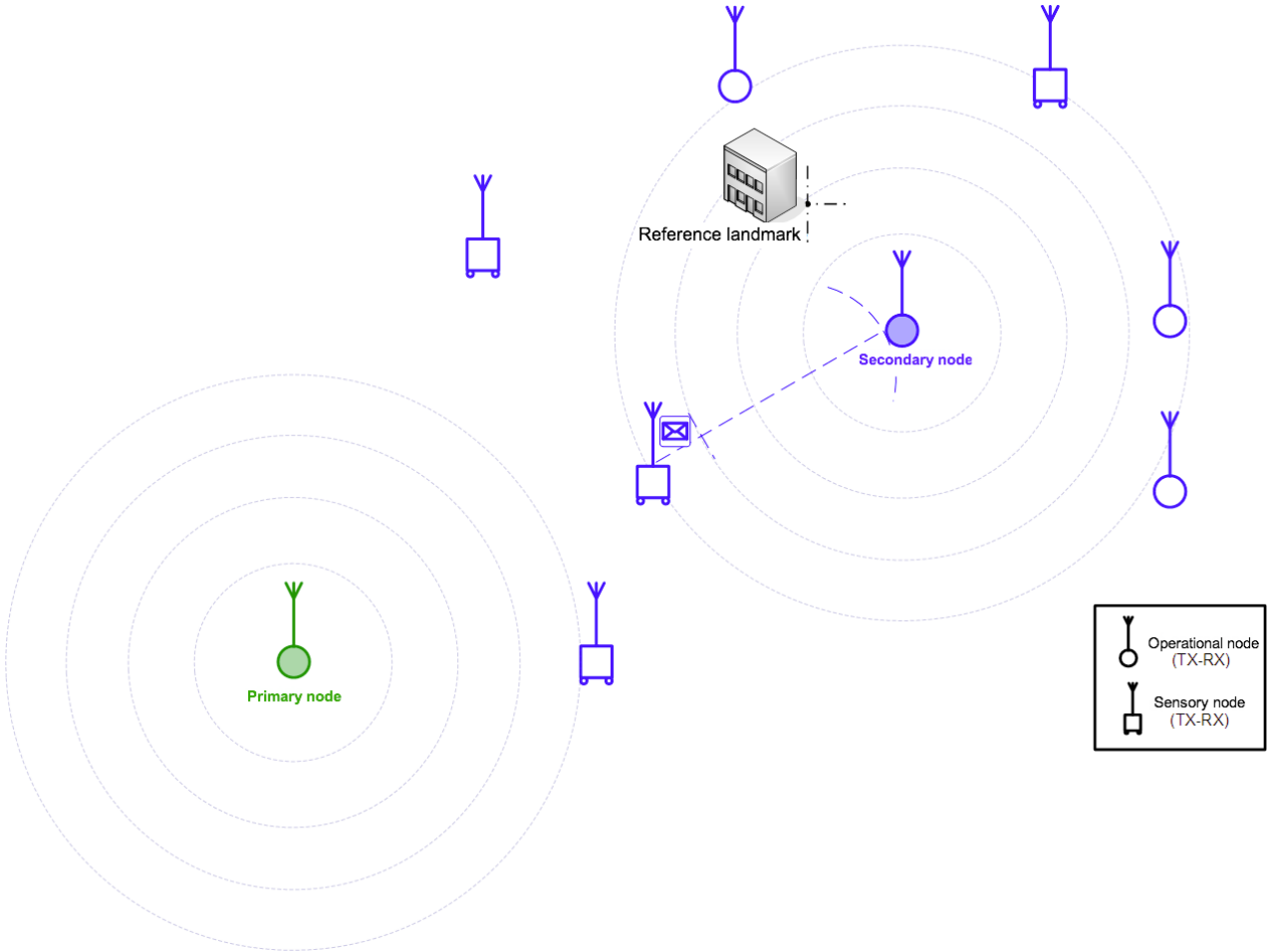


Figure: **Sensory node** positioned in the area detects the **primary** transmission and warns operational nodes within its range (*detection msg*).

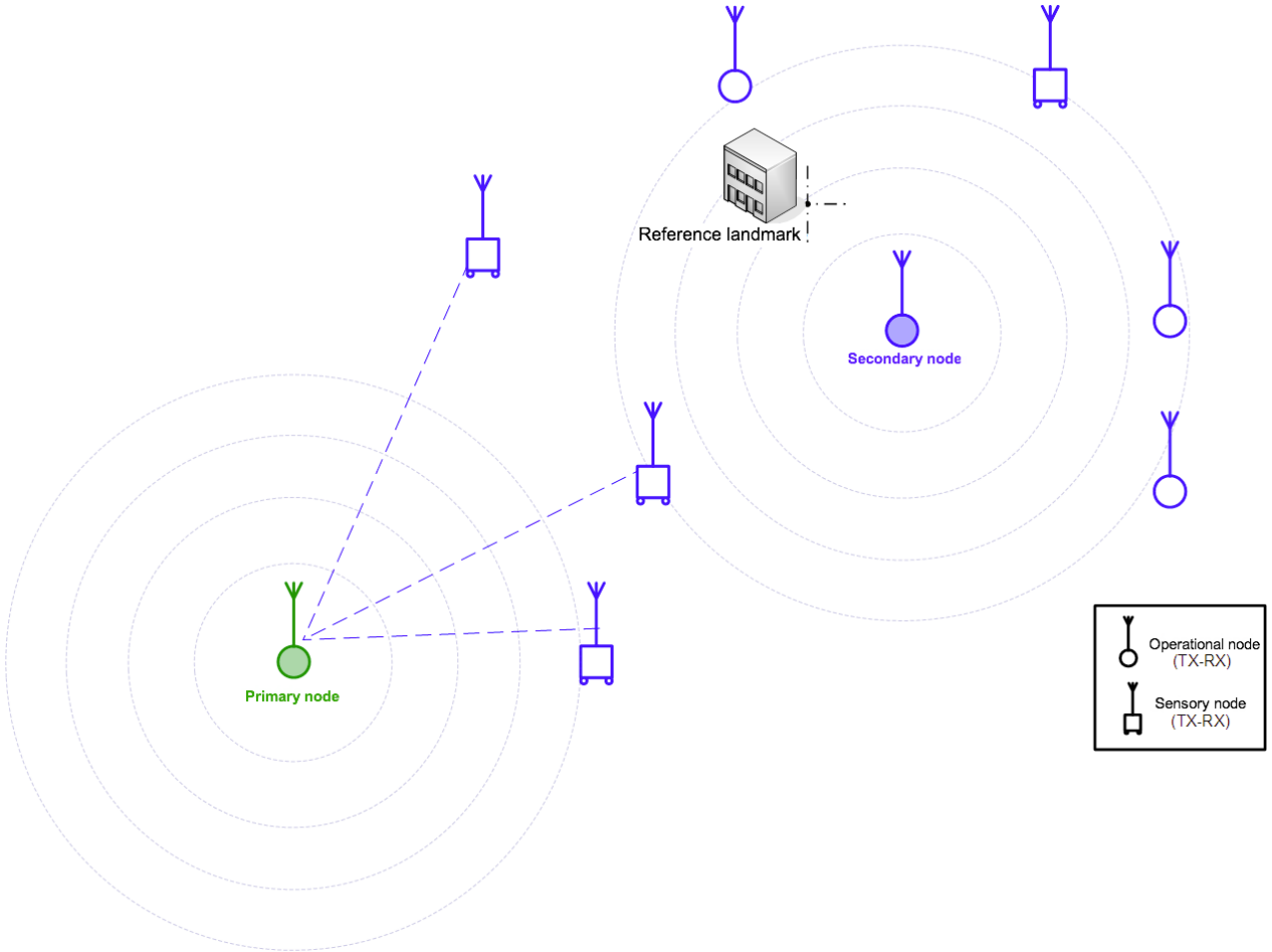


Figure: **Sensory nodes** infers the **primary** position based on the distance (RSSI) and the angle of arrival of the detected signal (AoA).

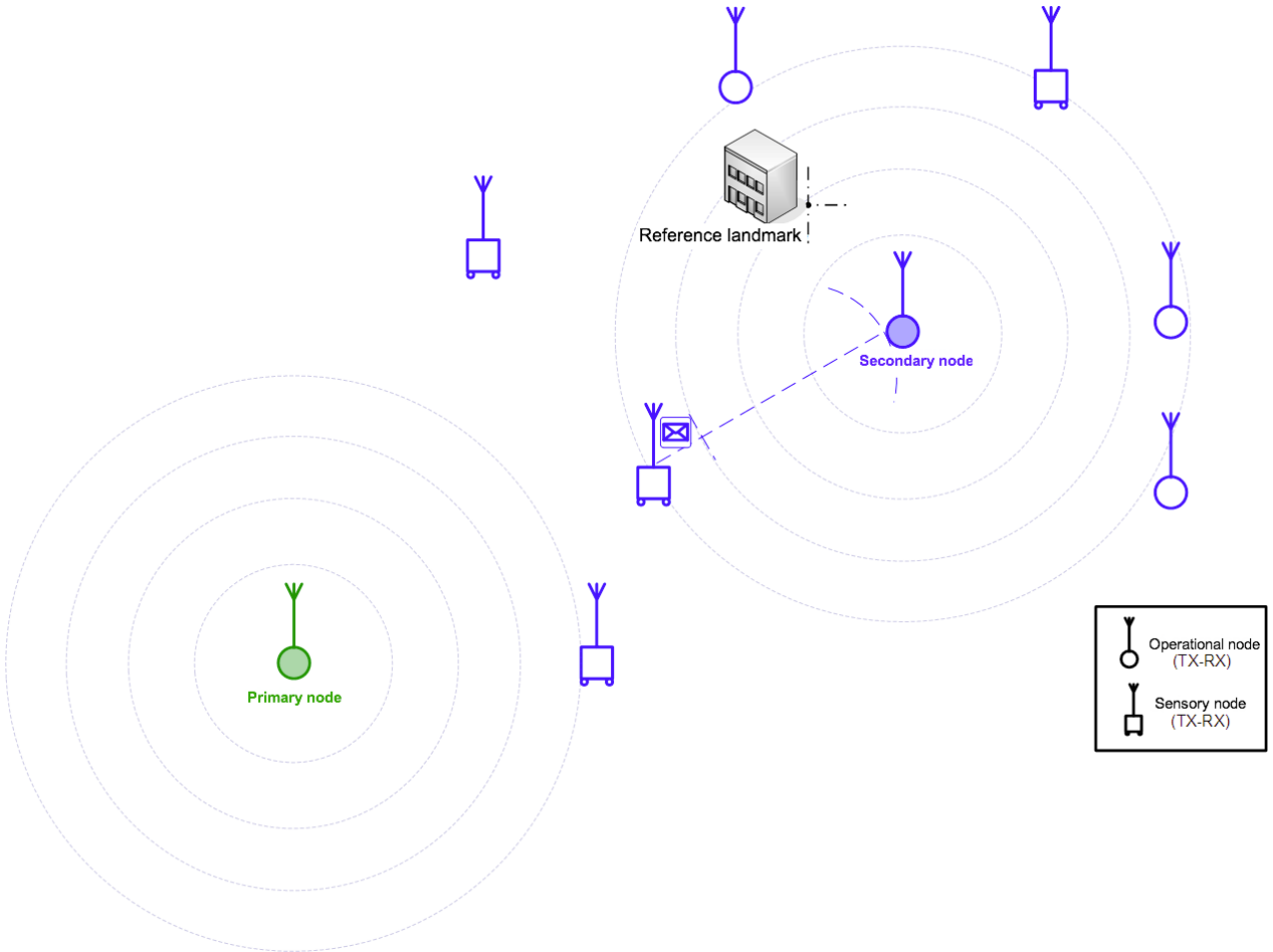
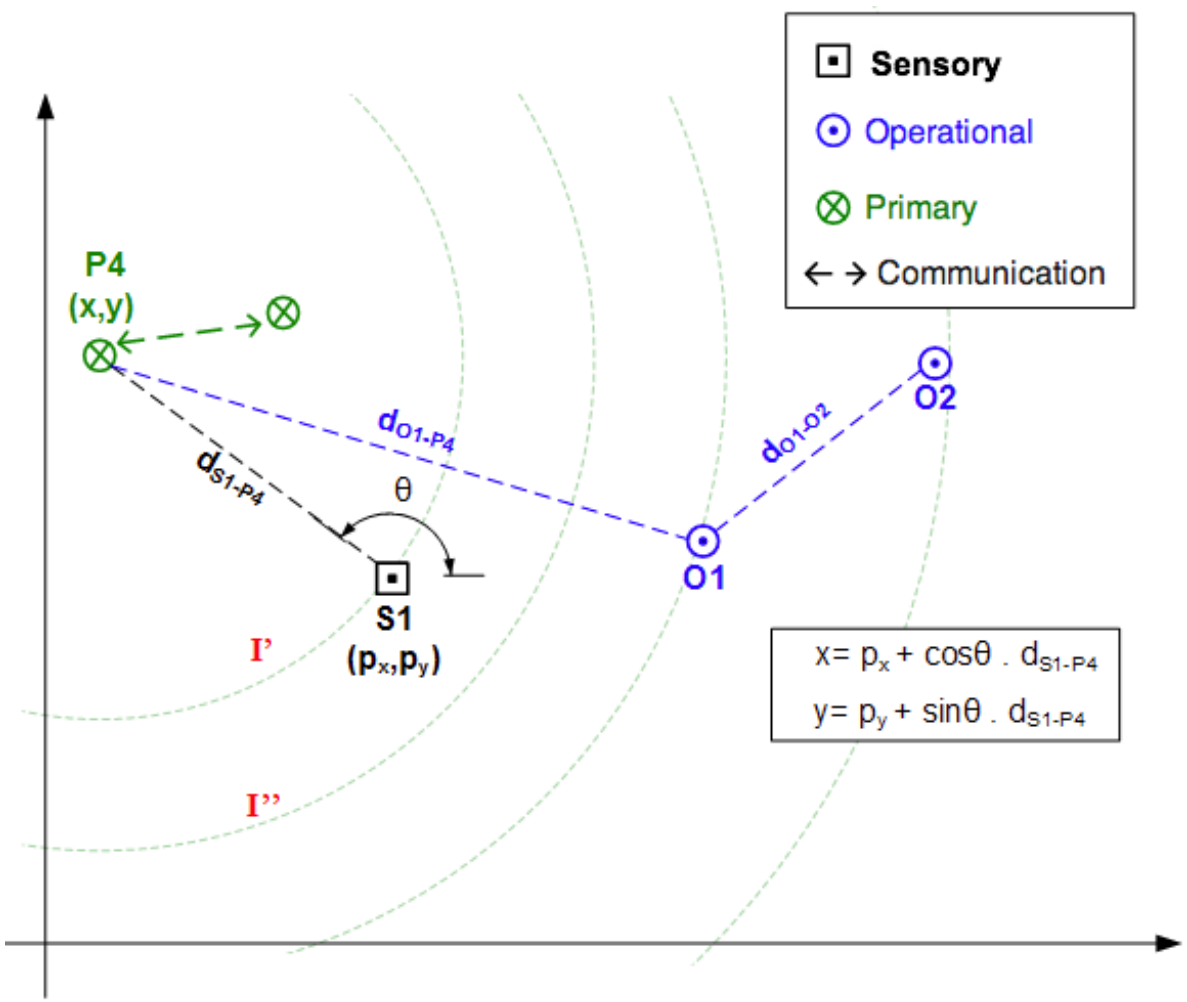


Figure: **Sensory nodes** provide feedback to **operational nodes** with the **estimated primary position** so the level of interference does not exceed the limits.

Primary location mechanism



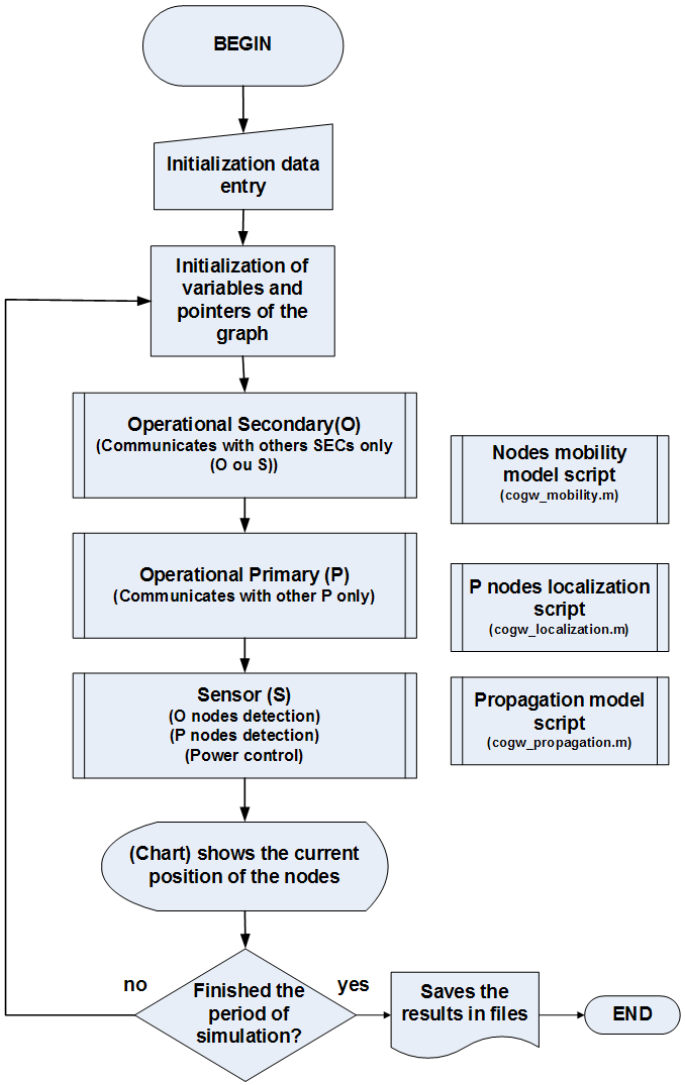
Power (transmission) control of operational node

Works from the information provided by sensory nodes that have made the detection/location.

Upon receipt of a *position message*, the operational node note of the estimated position of the primary node and promotes the adjustment of its transmission power, using the information contained in the message [a].

[a] The accuracy of the estimated position of the sending node and its distance will depend only on the number of sensory nodes who makes detection.

Flowchart of the simulator built with Matlab



Simulator variables

Name	Unit	Description
δ	%	Adjust factor
EIRP	dBm	Pt(dBm)+G_ant(dBi)-Loss(dBm)
L	%	Internal system loss
Gt/Gr	dB	Antenna gain
ht/hr	m	Antenna high
i_limit	dBm	Maximum interference level (P node)
V	m/s	Maximum velocity (mobile node)
d0	m	Reference distance, d_0

Simulator variables (cont.)

Name	Unit	Description
thru	KBps	Throughput (O and P nodes)
p_stream	-	ON/OFF source regulation
frame_size	Bytes	Frame length
ack_length	Bytes	ACK length
rts_length	Bytes	RTS length
cts_length	Bytes	CTS length
sifs	μs	SIFS
difs	μs	DIFS

Simulator variables (cont.)

Name	Unit	Description
slot_time	μs	Slot time
backoff	μs	Backoff
cwmin/cwmax	-	CWmin/CWmax
D	m	Side of square area
freq	GHz	Frequency
Y	$N(\mu; \sigma^2)$	Distance error (RSSI)
ϵ	%	Positioning error
ϕ	%	AoA error

Propagation model

Implemented

- Outdoor:
  - Free Space
  - Power Scale
- City (Urban):
  - Young Model (2 ray ground)
  - Okumura Model
  - Hata Model for Urban Areas
  - Hata Model for Suburban Areas
- Indoor:
  - Log-distance Path Loss Model

Initial Scenarios

- FIXED Scenario 1: 1 pair of operational nodes (O1 and O2), 1 pair of primary nodes (P1 and P2) e 2 sensory nodes (S1 and S2);
- FIXED Scenario 2: 2 pairs of operational nodes (O1 to O4), 1 pair of primary nodes (P1 and P2) e 2 sensory nodes (S1 and S2);
- FIXED Scenario 3: 2 pairs of operational nodes (O1 to O4), 2 pairs of primary nodes (P1 to P4) e 2 sensory nodes (S1 and S2);
- MOBILE Scenario 4: 2 pairs of operational nodes (O1 to O4), 2 pair of primary nodes (P1 to P4) e 2 sensory nodes (S1 and S2).

Scenarios

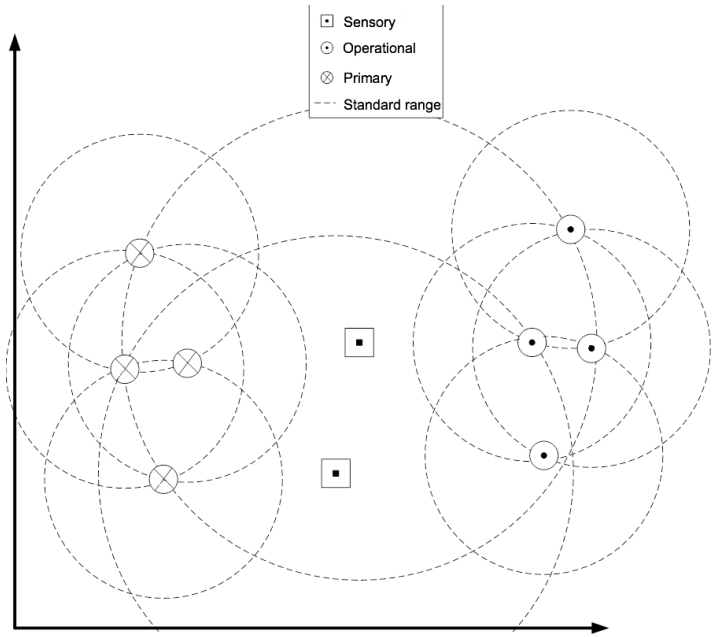


Figure: Positioning schema for FIXED scenarios.

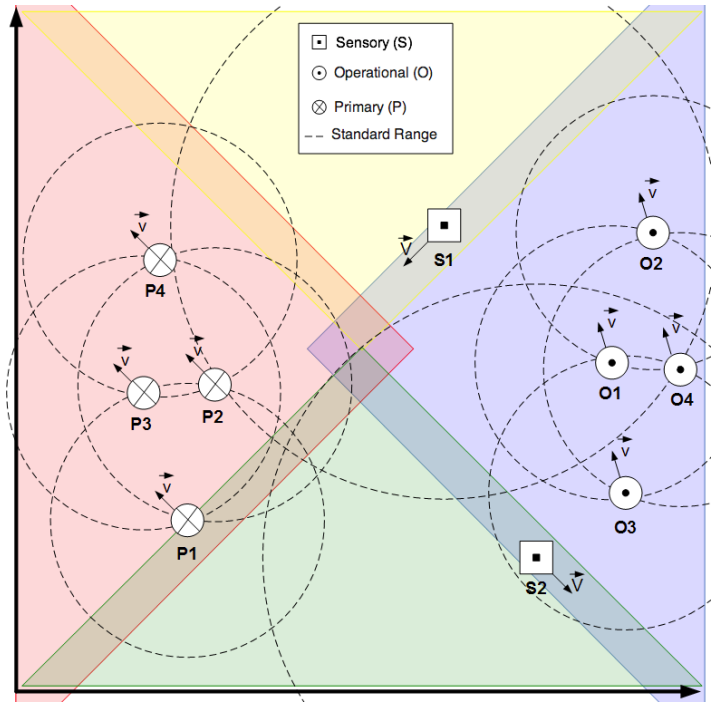


Figure: Positioning and mobility schema for MOBILE scenario.

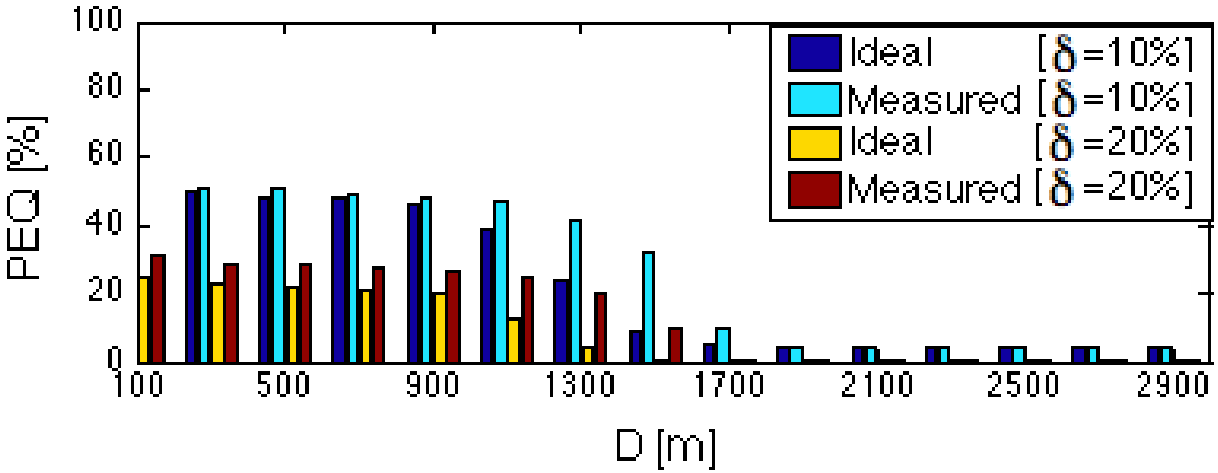
Variables Values

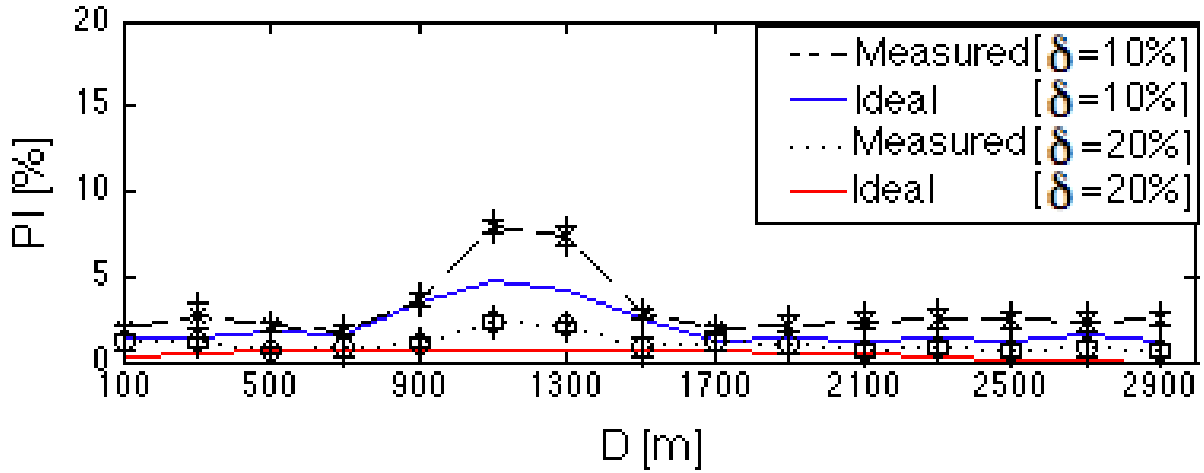
Name	Value	Content
D	100 m-3000 m	Side of square area
f	1 GHz	Frequency
$EIRP$	0 dBm	Pt x antenna gain
X	$N(0.5; 5^2)$	Log distance path loss
Y	$N(0.01d; 0.05d^2)$	Distance error (RSSI)
ϵ	1%	Positioning error
ϕ	1%	AoA error
d_0	41 m	Reference distance
δ	10%/20%	Adjust factor

Metrics

- Interference percentage (PI) $\rightarrow$ larger than I in the primary node transceiver considering a communication among operational nodes;
- Percentage of broken links (PEQ) $\rightarrow$ in secondary network through power control performed by operational nodes.

Scenario 1


PEQ [%]
D [m]
Ideal [δ=10%]
Measured [δ=10%]
Ideal [δ=20%]
Measured [δ=20%]
100
80
60
40
20
0
100
500
900
1300
1700
2100
2500
2900


PI [%]
D [m]
Measured [δ=10%]
Ideal [δ=10%]
Measured [δ=20%]
Ideal [δ=20%]
20
15
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100
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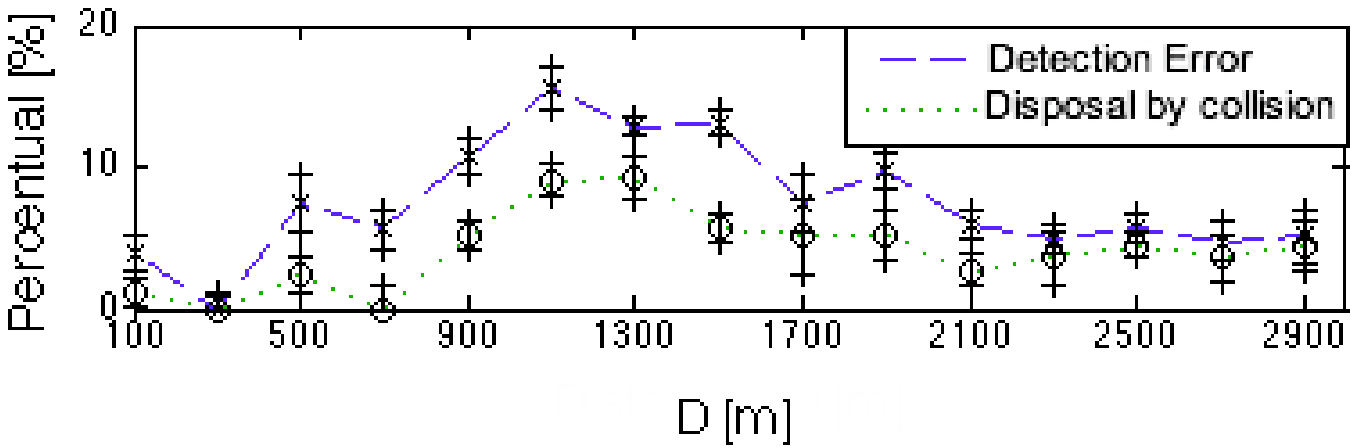
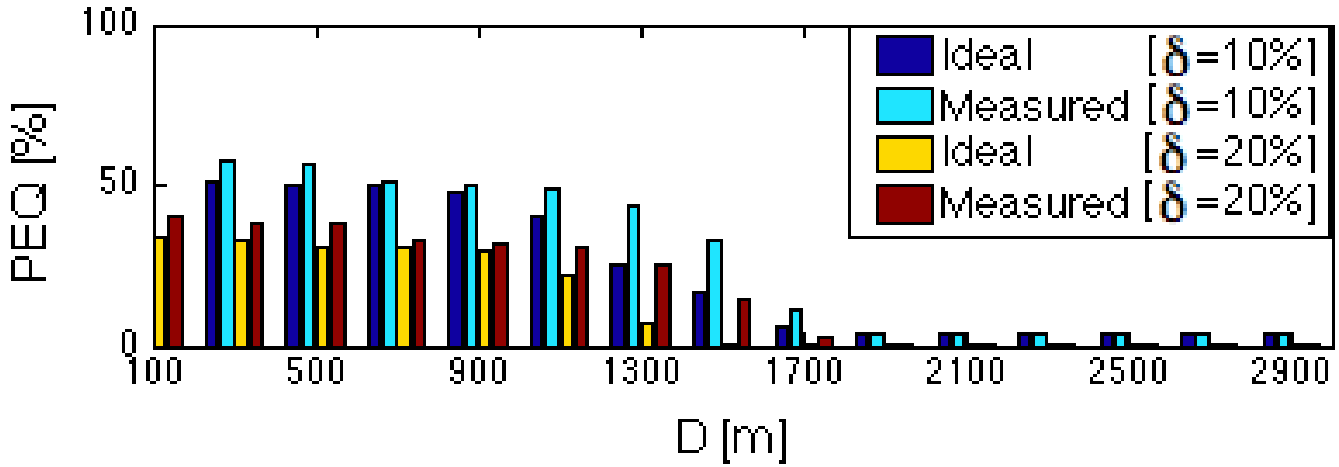
2500
2900

Scenario 1: Problems



Scenario 2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PEQ [%]
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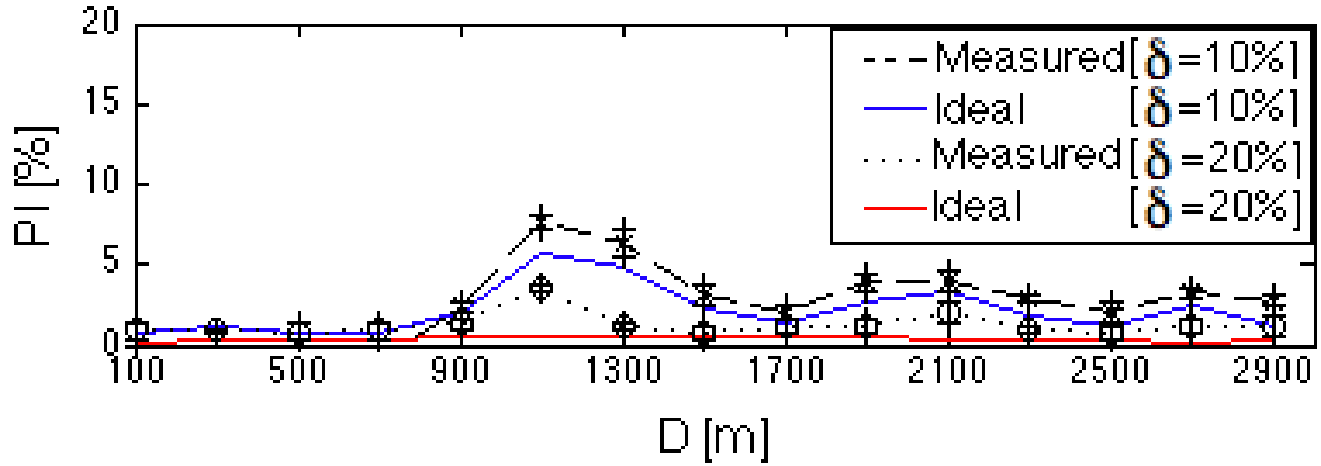
D [m]
Ideal [δ=10%]
Measured [δ=10%]
Ideal [δ=20%]
Measured [δ=20%]


20
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PI [%]
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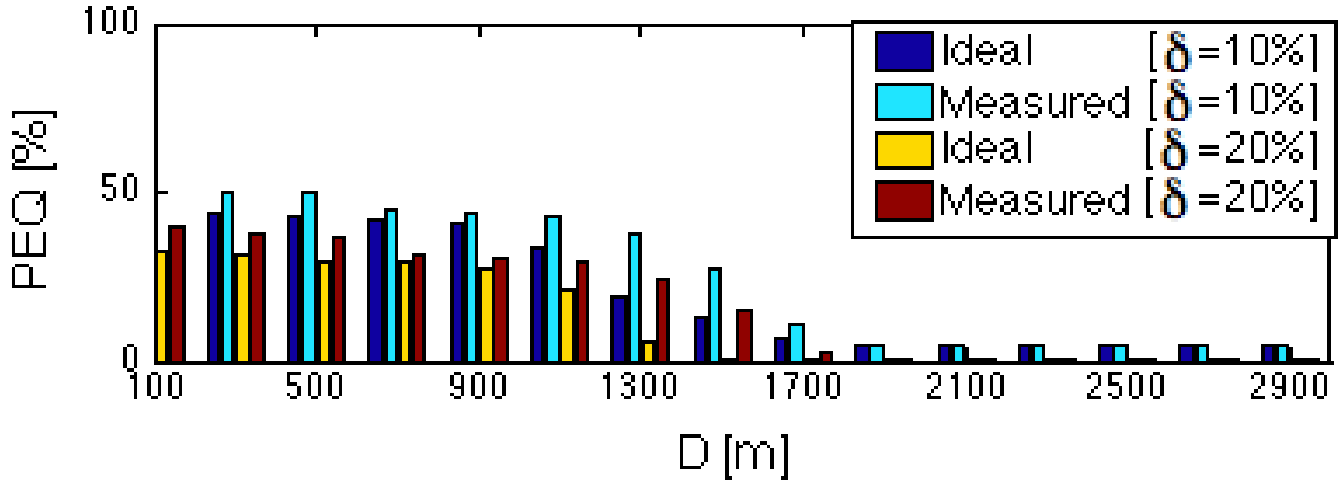
D [m]
Measured [δ=10%]
Ideal [δ=10%]
Measured [δ=20%]
Ideal [δ=20%]

Scenario 3


PEQ [%]
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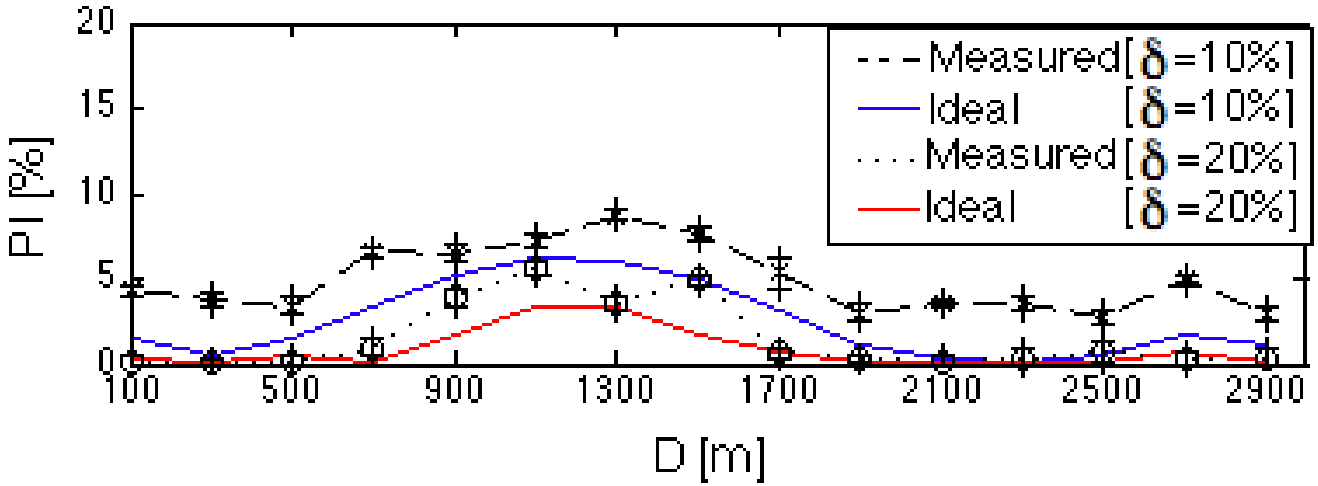
D [m]
Ideal [δ=10%]
Measured [δ=10%]
Ideal [δ=20%]
Measured [δ=20%]


PI [%]
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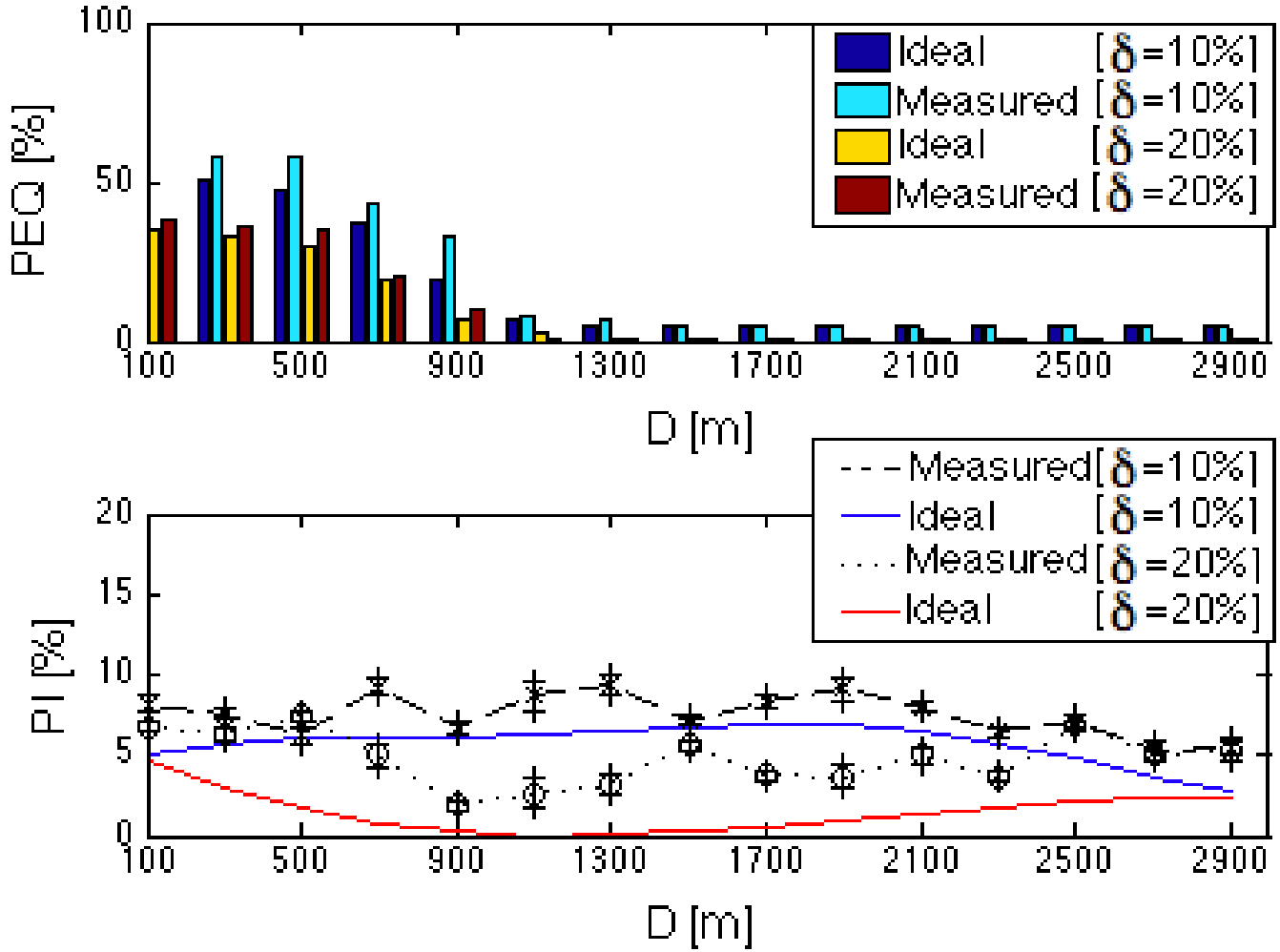
D [m]
Measured [δ=10%]
Ideal [δ=10%]
Measured [δ=20%]
Ideal [δ=20%]

Scenario 4


PEQ [%]
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1700
2100
2500
2900
D [m]
Ideal [δ=10%]
Measured [δ=10%]
Ideal [δ=20%]
Measured [δ=20%]
PI [%]
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900
1300
1700
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2500
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D [m]
Measured [δ=10%]
Ideal [δ=10%]
Measured [δ=20%]
Ideal [δ=20%]

Conclusions

Our results, with two *ad hoc* networks and FIXED and MOBILE nodes, show that we can implement a (simple) interference control on primary nodes with only a mechanism of individual positioning and a signal source detection system (goniometer).

- At the same time maintaining an acceptable connectivity level among secondary network nodes, a simple indicator of quality in the communications.

Future Work

- Adjust the location/positioning mechanism for greater effectiveness
- Implement a mechanism for collision reduction
- Establish other metrics and more "populated" scenarios for evaluation.

Thank you for your attention !
Questions ?

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