

Wireless Reliability for Smart-Grids: Directional Antennas

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Goals

Wireless-based Smart-Grid

Introduction

Experiments

Design
Realisation
Synchronization

Results

Losses
Coordinated
Bursts

Unexpected result

Conclusion

- Long-distance wireless links
- Upward data collection
- Downward orders
- Reliability in both directions

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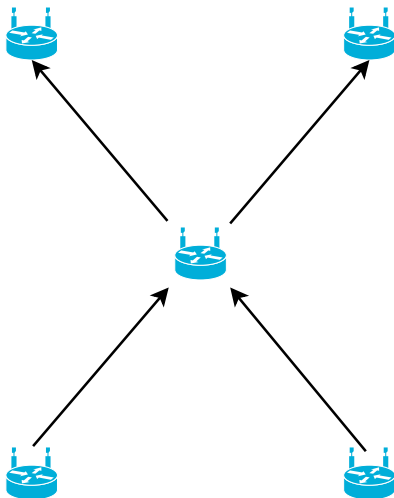
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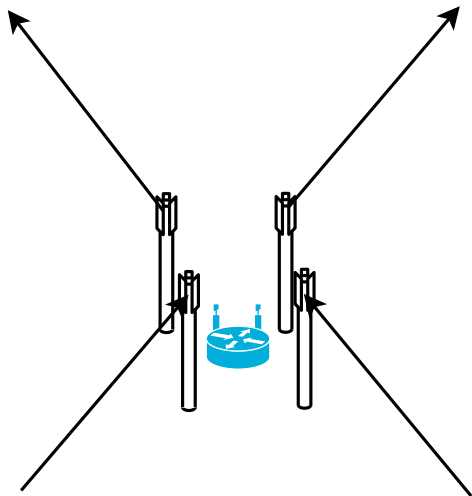
Goals

4 links per node



Goals

4 directional antennas per node



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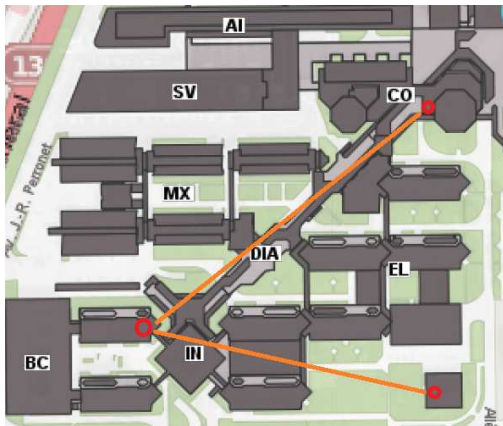
result

Conclusion

- Wireless links:
 - Directional antennas
 - 802.11g
 - Antennas on rooftops
- Periodic IPv6 UDP traffic (20ms)
- No retransmissions: use broadcast

Realisation

Roof selection



Links:

INN-CO: 225m

INN-ELL: 180m

Realisation

Installation



- *interline.pl* antennas
- *Aziala* routers

Realisation

Measures

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- One/two link(s) active
- Send packets with sequence ID on one/two link(s)
- Store:
 - Sending time
 - Sequence ID
 - Receive time
 - Received signal strength
 - Channel used
 - Source (IPv6)

Synchronization

Problem

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4 routers:

- Low precision internal clock
- No GPS/whatever clock module
- 2 isolated nodes

Synchronization

Solution

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- No synchronization of isolated nodes
→ Unsynchronized packet emission
- ntpd-synchronization on INN
- Re-synchronization of data:
 - *Simple* Algorithm: same time window
 - Experimentation: 3-4 resynchronization per hour

→ Lower collision probability than real system

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Loss probabilities

Rate	Duration	Link 1	Link 2	Simultaneous
6Mb/s	6h	2.7 ‰	1.0 ‰	0.03 ‰
6Mb/s	17h	1.5 ‰	0.8 ‰	0.01 ‰
36Mb/s	21h	2.6 ‰	4.3 ‰	0.09 ‰
36Mb/s	64h	2.0 ‰	1.9 ‰	0.03 ‰
48Mb/s	21h	12 ‰	17 ‰	0.3 ‰
54Mb/s	24h	41 ‰	79 ‰	3.9 ‰

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Simple coordinated losses

Model

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- Independent loss probability for each link: a & b
- Coordinated loss probability: c

	Loss	Success
Loss	$a * b * (1 - c) + c$	$(1 - a) * b * (1 - c)$
Success	$a * (1 - b) * (1 - c)$	$(1 - a) * (1 - b) * (1 - c)$

Simple coordinated losses

Results

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Coordinated loss probability (c) really small:

Rate	a	b	c
6Mb/s	1.5 ‰	0.8 ‰	0
36Mb/s	2.0 ‰	1.9 ‰	0
48Mb/s	12 ‰	17 ‰	1.2 ‰
54Mb/s	40 ‰	78 ‰	7.8 ‰

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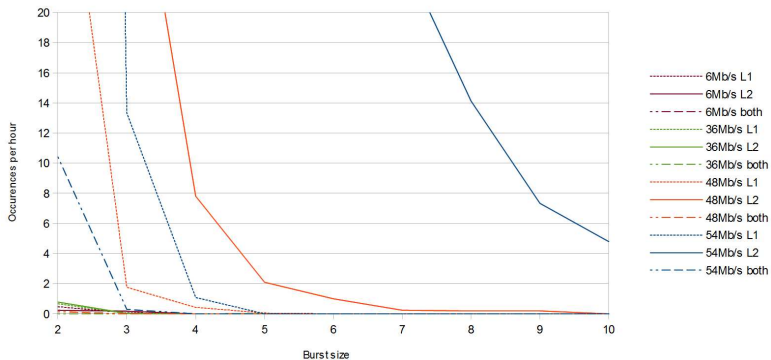
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Time auto-correlation graph

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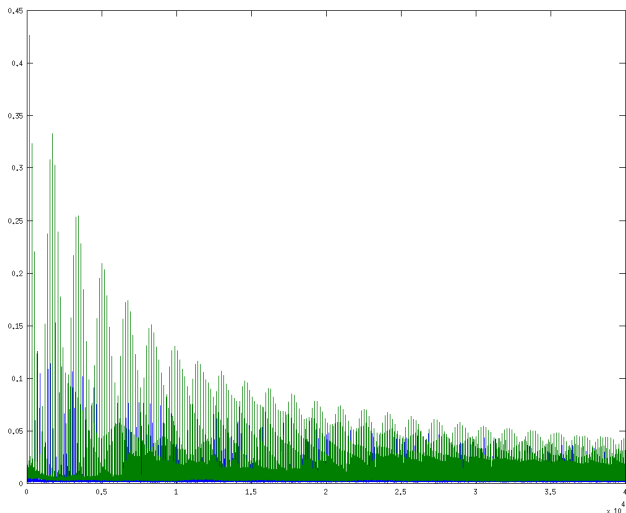
Conclusion

Trying to find time-correlation in losses:

$$(P(Loss(t)|Loss(T + t)))_T \approx \left(\frac{\sum_t \mathbb{1}_{Loss(t)|Loss(T+t)}}{\sum_t \mathbb{1}_{Loss(t)}} \right)_T$$

Unexpected result

36Mb/s, data on two links, channels 4-8 (1-5-9-13)



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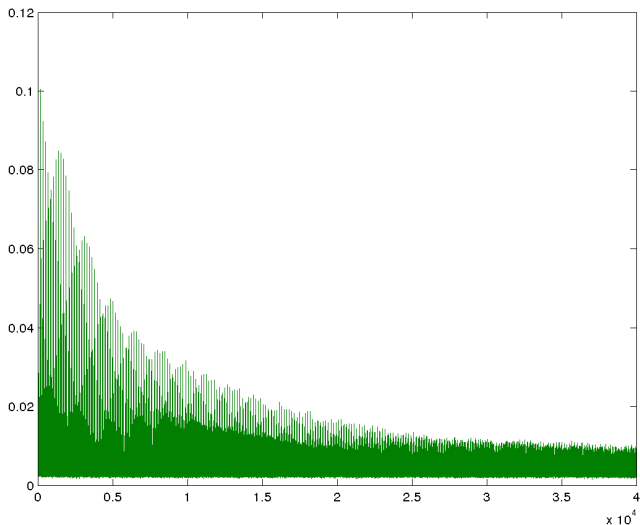
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36Mb/s, data on one links, channels 3-8 (1-6-11)



Unexpected result

Extremely periodic *Noise*

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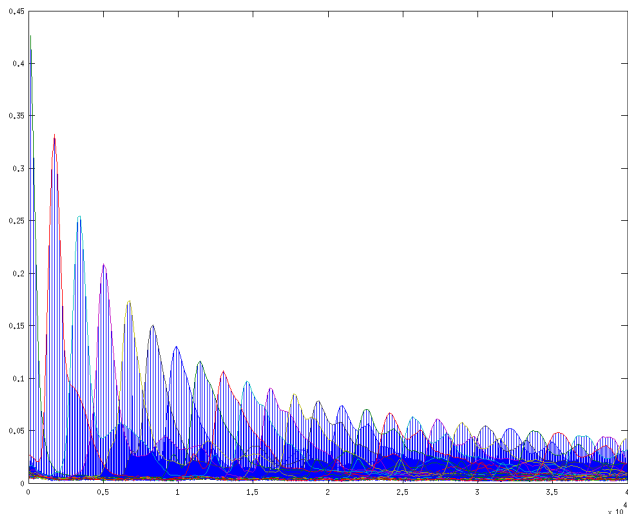
2 different periods:

- 169 (3.320s)
- 1562 (33.040s)

→ Curves extraction: $\forall k : X(k * 1562 + 169\mathbb{Z})$

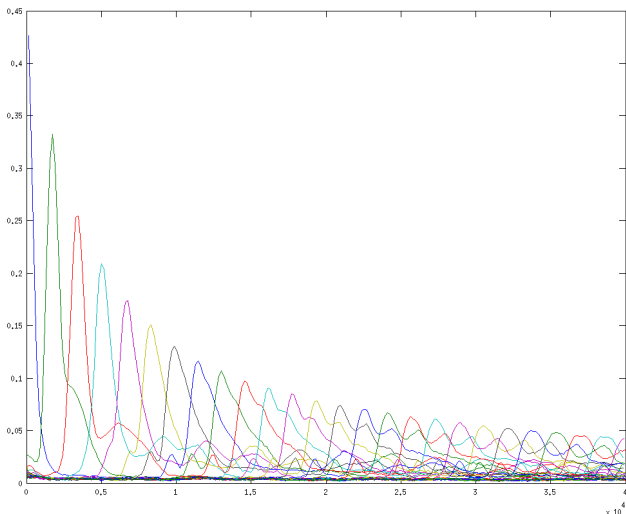
Unexpected result

36Mb/s, data on two links, channels 4-8 (1-5-9-13)



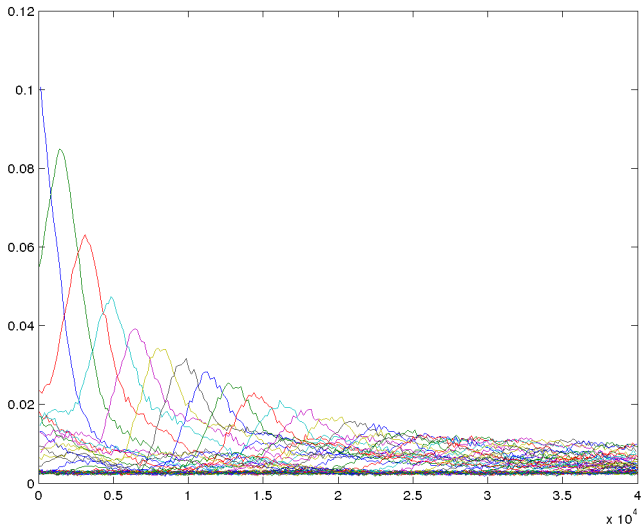
Unexpected result

36Mb/s, data on two links, channels 4-8 (1-5-9-13)



Unexpected result

36Mb/s, data on one links, channels 3-8 (1-6-11)



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		Link 1				Link 2					BC	Present
Channel	Rate	INN	CO	data	Channel	Rate	INN	ELL	data			
8	36Mb/s	✓	✓	✓	-	-	X	X	X	X	X	
8	36Mb/s	✓	✓	✓	4	6Mb/s	✓	X	X	X	X	
8	36Mb/s	✓	✓	✓	4	6Mb/s	✓	X	X	✓	X	
8	36Mb/s	✓	✓	✓	4	6Mb/s	✓	✓	X	✓	X	
8	36Mb/s	✓	✓	✓	4	36Mb/s	✓	✓	✓	✓	✓	
8	36Mb/s	✓	✓	✓	4	36Mb/s	✓	✓	✓	X	✓	
8	36Mb/s	✓	✓	✓	4	36Mb/s	✓	✓	X	X	✓	
8	36Mb/s	✓	✓	✓	3	36Mb/s	✓	✓	✓	X	✓	
8	36Mb/s	✓	✓	✓	3	36Mb/s	✓	✓	X	X	✓	
8	36Mb/s	✓	✓	✓	2	36Mb/s	✓	✓	X	X	X	

Unexpected result

Conclusion

- Data independent
- Rate dependent
- Channel dependent

→ Probably beacon related

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- Water-proof, wind-proof working measurement system
 - No clear collisions between incoming signal
 - Probably collisions between incoming and outgoing signals
- Need for antennas isolation

Thank you for your attention

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Questions ?