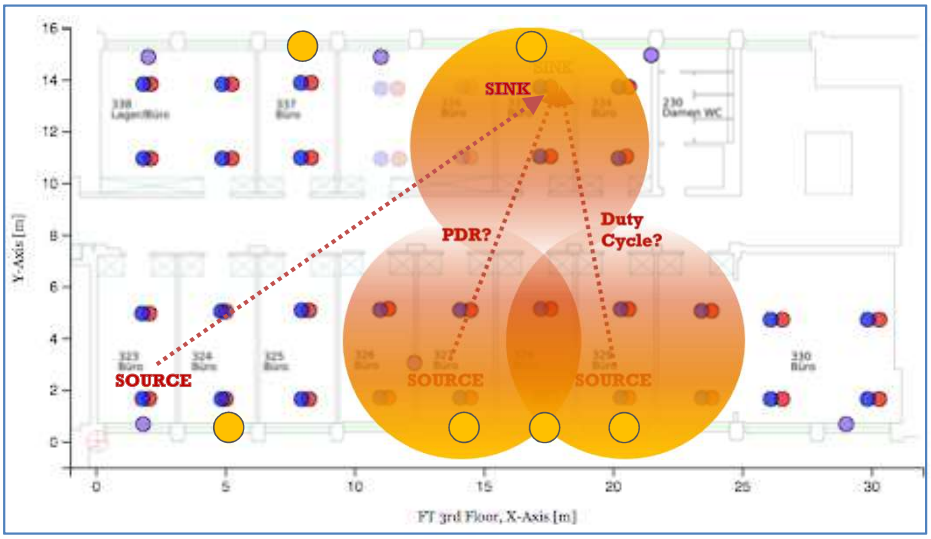
WiSHFUL

CrystalClear

Evaluating Synchronous Transmission Reliability under WiFi Interference in WiSHFUL

Wi-Fi + LLN co-existence
Recent research activities have shown that omnipresent Wi-Fi devices may impede data delivery with low power and lossy (LLN) networks. This project offers tools to expend the WiSHFUL testbeds for easy evaluation of LLN protocols under real, repeatable Wi-Fi interference scenarios

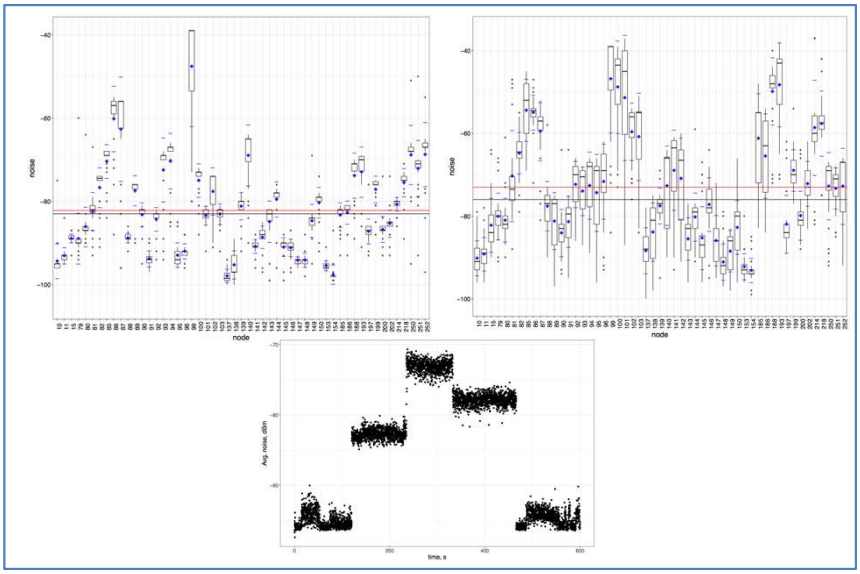


In the 3° floor map of the WiSHFUL TWIST testbed, yellow nodes are NUCs and blue nodes are TMoteSky WSN nodes. Our question: *When Wi-Fi flows are generated between (or among) NUCs, how is multi-hop data collection on the the co-located LLN network affected in terms of PDR and energy efficiency (expressed in terms of duty cycle).*

Wi-Fi Flow definition
```
flow0:
  flow_id: 0
  interface: "wlan0"
  channel: 11
  ch_width: 20
  ap: "nuc4"
  src: "nuc12"
  dst: "nuc4"
  transport: "UDP"
  udp_bandwidth: "200M"
```

Wi-Fi Flow definition
```
flow1:
  flow_id: 1
  interface: "wlan0"
  channel: 11
  ch_width: 20
  ap: "nuc10"
  src: "nuc6"
  dst: "nuc10"
  transport: "UDP"
  udp_bandwidth: "200M"
```

Wi-Fi Flow timing
```
schedule:
  - start: flow0
  - wait:  120
  - start: flow1
  - wait:  100
  - stop   flow0
  - wait   130
  - stop:  flow1
```



DEFINING REUSABLE INTERFERENCE PATTERNS:
a new WiSHFUL module

We use point to point Wi-Fi flows between pairs of NUCs to generate interference. A configuration file (see left) defines the parameters of each flow and a schedule for starting and stopping the flows during an experiment.

INTERFERENCE CHARACTERIZATION

To understand the generated interference and its influence on the co-located 802.15.4 network, a new tool runs in the WiSHFUL TWIST-Sensor network to monitor the noise levels perceived by each node in the testbed. The figure on the top left shows a single flow, while the figure on the top right shows the impact of two, simultaneous nodes. We can see a rise in the average noise (the red bar in both figures) as well as the increase influence on individual nodes (indicated separately on the X-axis). The figure on the bottom shows the network-wide interference of both flows over time with the following sequence: no interference, one flow, two flows, one flow, and finally no interference. Using this tool we can evaluate the generated interference on different elements of the LLN network, e.g., a node chosen as a sink, as a source, etc.

CrystalClear

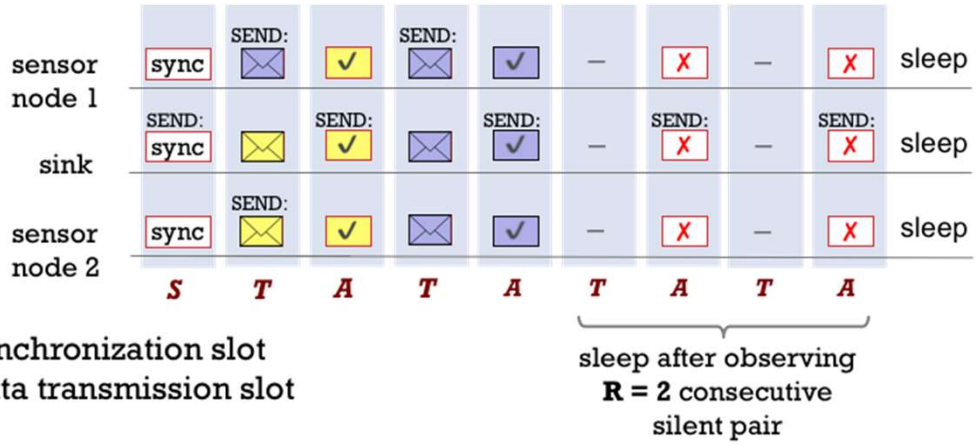
Crystal

Crystal defines a network-wide transport protocol in which:

- a **transmission** (T) slot is used by U concurrent senders to disseminate their packet; these floods *compete* until, thanks to the capture effect and Glossy redundancy, one reaches the sink with high probability
- an **acknowledgment** (A) slot is used by the sink to flood the identifier of the sender whose packet it received, informing the others whether re-transmission is needed because their packet was *overcome* by another or no packet was received at the sink.

We extended Crystal with two interference resiliency techniques.

- ***Escape*** : we use network-wide ***channel hopping*** to enable subsequent TA pairs to move to different channels, reducing the probability that two consecutive ones both execute on noisy channels.
- ***Fighting***: we ***detect abnormally high noise*** and adapt R, the termination condition



Crystal in the WiSHFUL TWIST testbed

We ran Crystal with and without these extensions in WiSHFUL TWIST (TMote), with and without WiSHFUL Wireless (NUC) generated Wi-Fi interference.

	U=1	U=20
PDR, %	100	100
Mean ON time, ms	39.4	215
Max ON time, ms	42.6	248

Baseline Crystal: no noise

	Crystal	Crystal+CH		Crystal+ND		Crystal+CH +ND
	U=1	U=1	U=20	U=1	U=20	U=20
PDR, %	21	100	99.76	69	8	99.98
Mean ON time, ms	34.4	40.9	274	121	151	281
Max ON time, ms	59.9	45.6	322	193	253	331

Crystal: under one Wi-Fi, UDP flow near the sink

From these results we see that the techniques added to Crystal to combat interference bring the performance back on par to results without interference, with an expected increase in energy consumption.

The existence of the new tools to generate Wi-Fi flows in WiSHFUL allow these tests to easily be repeated with other protocols and for other scenarios to be easily evaluated.