Poster Abstract: Preliminary results on LoRaWAN and IEEE 802.15.4-SUN Interference

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ABSTRACT

We present some preliminary results on LoRaWAN and IEEE 802.15.4-SUN interference in urban environments. The results are based on a simple simulation that is parameterized using PHY layer measurements of controlled interference scenarios.

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1 INTRODUCTION

A variety of new radio technologies provide low-power, low-bitrate, long-range communication in sub-GHz spectrum. Low-power wide-area networks (LPWANs) based on these radios are proposed for IoT and Smart Environment applications. Because they operate in unlicensed spectrum, LPWAN radios and network architectures are quite diverse.

Some LPWANs, such as SigFox and LoRaWAN, are based on cellular network models. Base stations are installed in preferred locations and have large, high-gain antennas. They provide coverage to subscriber devices over ranges of up to tens of km, at data-rates of up to a few kbps. Traffic is almost exclusively uplink and MAC functionality is minimal; senders are constrained by regulatory limits on output power and duty cycle.

Other LPWANs are based on local access points or multi-hop forwarding. The IEEE 802.15.4 PHY specification includes a variant for sub-GHz Smart Utility Networks (SUN). It provides bitrates of 50–200 kbps over ranges of 1–2 km. These networks support IEEE 802.15.4 CSMA- and TSCH-based MAC layers, as well as higher-layer standards such as 6LowPAN and 6TiSCH.

Because these networks operate in unlicensed spectrum, there will be many independently deployed networks operating in the same area. Although performance of sub-GHz networks for Smart Utilities has been studied (e.g. [4]), little is known about cross-technology interference. We performed a simple Python simulation of the potential impact of LoRaWAN networks on IEEE 802.15.4-SUN networks. The simulation is based partly on our earlier measurement study of PHY layer interactions between LoRa and IEEE 802.15.4 transmissions [2, 3].

The preliminary results presented here allow us to interpret this low-level measurement data in the context of Smart Utility applications operating in an urban area. They also contribute to the design of further measurement studies and the development of more sophisticated simulation and testbed tools.

2 SIMULATION AND RESULTS

The simulation combines a empirical model of IEEE 802.15.4 packet loss under LoRa radio interference with a standard model of sub-GHz path loss in urban environments.

The packet loss model is based on experimental measurements of IEEE 802.15.4 packet reception rates under controlled LoRa interference conditions. Figure 1 shows a subset of the data. Logistic regression was used to parameterize a model of the probability of IEEE 802.15.4 packet reception, given the strength of the IEEE 802.15.4 signal and the LoRa interference. A linear regression was used to parameterize a model of IEEE 802.15.4 clear channel assessment (CCA), given the strength of the LoRa interference.

The simulation scenario focuses on the impact of LoRaWAN on IEEE 802.15.4-SUN. The LoRa radio's CSS modulation is quite resilient to interference and LoRaWAN gateway antennas are often installed on rooftops or towers. By contrast, IEEE 802.15.4-SUN networks are more likely to operate closer to ground level, using local access points or multi-hop routing protocols, such as RPL. This means that the (predominantly uplink) LoRaWAN traffic is relatively unaffected by interference from IEEE 802.15.4-SUN networks. It also means that both IEEE 802.15.4-SUN senders and receivers may be located close to LoRaWAN senders and affected by their uplink transmissions. Moreover, LoRaWAN devices do not sense the channel and defer to ongoing transmissions.

In our simulation, LoRaWAN and IEEE 802.15.4-SUN devices are randomly positioned on a 10km x 10km field and path loss values between each device pair are calculated using the IEEE TGah model [1] for urban pico-cells with antenna height at 2 m.

IEEE 802.15.4-SUN transmissions use channel 26, with center frequency 868.325 MHz. This is near the middle of the three 125 kHz channels used by LoRaWAN, with center frequencies at 868.1, 868.3

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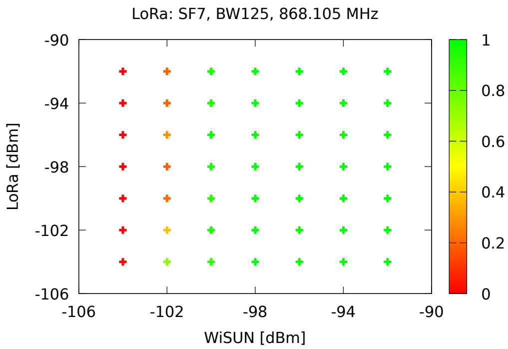

Figure 1: Probability of IEEE 802.15.4 packet reception for various IEEE 802.15.4 and LoRa received signal strengths.

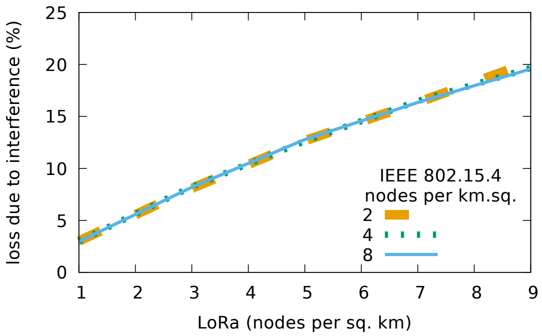

Figure 2: IEEE 802.15.4-SUN packet loss due to LoRaWAN interference on 868.1 MHz.

and 868.5 MHz. The default IEEE 802.15.4-SUN modulation (GFSK at 25 kHz deviation, 50 kbps) and max output power (14 dBm) are used for all transmissions. Devices are assumed to be connected if the received signal strength is higher than the sensitivity (−110 dBm).

In 868.0–868.6 MHz spectrum, LoRaWAN devices are restricted to a transmit duty cycle of $< 1\%$. We use a more conservative value of 0.1% (~800 packets per day). LoRaWAN devices transmit at the maximum allowed power (14 dBm), using the default modulation of SF 7 and BW 125 kHz (~5.5 kbps).

For a randomly chosen connected IEEE 802.15.4-SUN device pair and set of active LoRaWAN senders (based on the duty cycle), the path loss and probability of packet reception models are used to determine whether the transmission succeeds. For simplicity, we ignore possible collisions between IEEE 802.15.4-SUN transmissions. In addition, only the strongest LoRaWAN interferer is assumed to affect packet reception. The results reflect 50,000 transmissions in each of 50 randomly generated topologies.

Figure 2 shows results for the case where LoRaWAN senders are using the 868.1 MHz LoRaWAN channel. This channel has only partial overlap with the IEEE 802.15.4-SUN channel 26. This mitigates the impact of LoRaWAN on the IEEE 802.15.4-SUN transmissions. But the IEEE 802.15.4-SUN senders also have limited ability to reliably sense LoRaWAN transmissions, and we assume here that CCA is not possible.

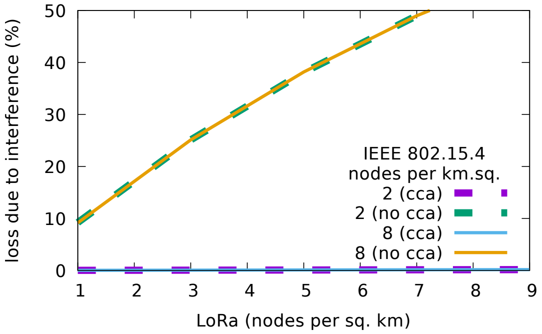

Figure 3: IEEE 802.15.4-SUN loss due to LoRaWAN interference on 868.3 MHz. With CCA, loss is <1%.

The simulation scenarios vary the number of IEEE 802.15.4-SUN devices (2 to 8 per km^2) and the number of LoRaWAN interferers (1 to 9 per km^2). With low LoRaWAN densities, there is often either no active LoRaWAN sender or its interference is too low to matter. However, the impact of LoRaWAN becomes significant as the LoRaWAN density increases. Because the IEEE 802.15.4-SUN links are uniformly distributed, there is (unrealistically) little dependence on IEEE 802.15.4-SUN density.

The 868.3 MHz LoRaWAN channel is mostly coincident with IEEE 802.15.4-SUN channel 26. The receiver is therefore highly vulnerable to LoRaWAN interference. We model the probability that the IEEE 802.15.4 CCA detects the presence of an interfering transmission. If interference is detected, the packet is assumed to be successfully transmitted later. Figure 3 shows that the CCA mechanism is highly effective in this scenario.

3 CONCLUSION

As IoT and Smart environment applications become more widely deployed, there will be complex interactions between networks operating in same location and sharing unlicensed spectrum. Our results suggest that LoRaWAN interference causes packet loss in IEEE 802.15.4-SUN networks, which becomes significant as the density of LoRaWAN devices increases, especially without effective CCA mechanisms. The simulation reported here is based on interference measurements under controlled conditions, but is otherwise highly simplified. It would be worthwhile to further investigate using more sophisticated simulation and testbed tools, particularly with regard to the role of the IEEE 802.15.4 MAC layer.

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