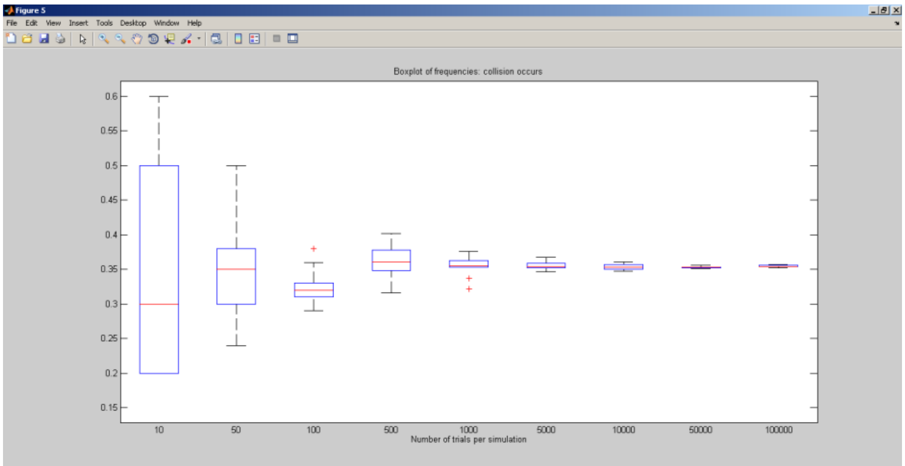

Figure 5: Box plot in case of collision when the no. of headers is less than one

6. Conclusion

This paper presents a careful analysis of the IEEE 802.15.4 and 802.11 interference patterns at 2.4 GHz ISM band. We examine these interference patterns at a bit-level granularity and we explain how a 15.4 node may change the behavior of nearby 802.11 transmitters under certain conditions. The paper introduces an algorithm allowing fast computation of the IEEE 802.11 contention-related characteristics and outcome in terms of probabilities associated with the respective wireless stations. This model and algorithm help understand the nature of the contention process in terms of two parameters per station , and allows evaluating the effect of different WLAN MAC parameters on the probability of gaining access to the shared wireless medium for the corresponding IEEE 802.11-2012 access categories. The suggested method was evaluated in a demonstration scenario and the obtained results agree with the simulation as well as with the empirical expectations. We are aware that the model does not yet reflect some of the important characteristics of real network traffic first of all, the model does not capture the interrupted attempts to access the medium, with reactions to collisions, and we also did not consider variable traffic intensity for different access categories. However, dynamic network behavior could be modeled with our tool, which would have to be applied round-to-round, where our algorithm would be the lowest-level computing routine. In such occasions, the exactness achieved by our algorithm has to be paid by some memory and computational load. Imagine that in a realistic scenario, a huge Markov chain (involving several contentions and repetitions caused by collisions) could be generated by using our algorithm, but it would be much more complex and computationally expensive to evaluate in comparison to the models originating in Bianchi's work.

References

[1] Cyber-physical systems executive summary," Tech. Rep., March 2008. [Online]. Available: http://varma.ece.cmu.edu/Summit/

[2] Chipara, O., Lu, C., Bailey, T.C., and Roman, G.-C., Reliable Clinical Monitoring using Wireless Sensor Networks: Experience in a Stepdown Hospital Unit, in Proceedings of the ACM Conference on Embedded Networked Sensor Systems (SenSys'10), Zurich, Switzerland, November 2010, pp. 155-168.

[3] Gaotao Shi, Zenghua Zhao, Yantai Shu, Shuangli Han. Monitoring the High-voltage Transmission Lines Based On Two-tier Wireless Networks. The Fourth ACM International Workshop on Wireless Network Testbeds, Experimental Evaluation and Characterization (collocated with ACM Mobicom). Beijing China, September, 2009.

[4] J. Ko, T. Gao, and A. Terzis. Empirical Study of a Medical Sensor Application in an Urban Emergency Department. Proceedings of the Fourth International Conference on Body Area Networks (BodyNets), Brussels, Belgium, 2009.

[5] J.-H. Hauer, V. Handziski, and A. Wolisz. Experimental Study of the Impact of WLAN Interference on IEEE 802.15.4 Body Area Networks. Proc. of 6th European Conference on Wireless Sensor Networks (EWSN), Cork, Ireland, February, 2009.

[6] Shucheng Liu, Guoliang Xing, Hongwei Zhang, Jianping Wang, Jun Huang, Mo Sha, Liusheng Huang, "Passive Interference Measurement in Wireless Sensor Networks, The 18th IEEE International Conference on Network Protocols (ICNP), Kyoto, Japan, on October 5-8, 2010

[7] Adaptive Frequency Hopping for Reduced Interference between Bluetooth® and Wireless LAN, Charles Hodgdon, Ericsson Technology Licensing, May 2003.

[8] R. Musaloiu-E. and A. Terzis. Minimising the Effect of WiFi Interference in 802.15.4 Wireless Sensor Networks. International Journal of Sensor Networks, 3(1):43–54, 2007.

[9] Jun Huang, Guoliang Xing, Gang Zhou, Ruogu Zhou, Beyond Coexistence: Exploiting WiFi White Space for ZigBee Performance Assurance, The 18th IEEE International Conference on Network Protocols (ICNP), Kyoto, Japan, on October 5-8, 2010

[10] Liang, C.M., Priyantha, B., Liu, J., and Terzis, A. Surviving wi-fi interference in low power ZigBee networks. In Proceedings of the ACM Conference on Embedded Networked Sensor Systems （SenSys'10）.2010, 309-322

[11] Soo Young Shin, Sunghyun Choi, Hong Seong Park, Wook Hyun Kwon:: Packet Error Rate Analysis of IEEE 802.15.4 Under IEEE 802.11b Interference. Lecture Notes in Computer Science, 2005: 279- 288

[12] B. Sklar, "Digital Communication", *Prentice Hall*, 1995 [13] J. Jeong and C.-T. Ee. Forward Error Correction in Sensor Networks. In WWSN, 2007.
[13] S. Kim, R. Fonseca, and D. Culler. Reliable Transfer on Wireless Sensor Networks. In SECON, 2004.
[14] J. Ko, T. Gao, and A. Terzis. Empirical Study of a Medical Sensor Application in an Urban Emergency Department. In BodyNets, 2009.
[15] C.-J. M. Liang, J. Liu, L. Luo, A. Terzis, and F. Zhao. RACNet: A High-Fidelity Data Center Sensing Network. In SenSys, 2009.
[16] Measurement Computing Corp. USB-2523: USB-Based 16 SE/8 DI Multifunction Measurement and Control Board. Available from: http://www.mccdaq.com/usb-data-acquisition/ USB-2523.aspx, 2009.
[17] R. Musaloiu-E. and A. Terzis. Minimising the Effect ofWiFi Interference in 802.15.4 Wireless Sensor Networks. International Journal of Sensor Networks, 3(1):43–54, 2007.
[18] Phil Karn. Reed-Solomon Coding/Decoding Package v1.0. Available at http://www.piclist.com/tecHREF/method/error/ rs-gp-pk-uoh-199609/index.htm., 1996.
[19] J. Polastre, R. Szewczyk, and D. Culler. Telos: Enabling Ultra-Low Power Wireless Research. In IPSN/SPOTS, 2005.
[20] S. Pollin, I. Tan, B. Hodge, C. Chun, and A. Bahai. Harmful Coexistence Between 802.15.4 and 802.11: A Measurement-based Study. In CrownCom, 2008.
[21] RF Micro Devices, Inc. ML2724 2.4 GHz Low-IF 1.5 MBps FSK Transceiver. Available from: http://www.rfmd.com/CS/ Documents/ML2724_ML2724SPACEDatasheet.pdf, Dec. 2005.
[22] S. Y. Shin, H. S. Park, and W. H. Kwon. Mutual Interference Analysis of IEEE 802.15.4 and IEEE 802.11b. Computer Networks, 51(12):3338 – 3353, 2007.
[23] H. Soude, M. Agueh, and J. Mehat. Towards An optimal Reed Solomon Codes Selection for Sensor Networks: A Study Case Using TmoteSky. In PE-WASUN, 2009.
[24] K. Srinivasan, M. Kazandjieva, S. Agarwal, and P. Levis. The Bfactor: Measuring Wireless Link Burstiness. In SenSys, 2008.
[25] Texas Instruments. 2.4 GHz IEEE 802.15.4 / ZigBee-ready RF Transceiver. Available at http://www.chipcon.com/files/ C2420_Data_Sheet_1_3.pdf, 2006.
[26] G. Thonet, P. Allard-Jacquin, and P. Colle. ZigBee - WiFi Coexistence: White Paper and Test Report. Technical report, Schneider Electrics, 2008.
[27] C. Won, J.-H. Youn, H. Ali, H. Sharif, and J. Deogun. Adaptive Radio Channel Allocation for Supporting Coexistence of 802.15.4 and 802.11b. In VTC, 2005.
[28] A. Woo and D. Culler. A Transmission Control Scheme for Media Access in Sensor Networks. In MobiCom, 2001.
[29] G. Zhou, Y. Wu, T. Yan, T. He, C. Huang, J. A. Stankovic, and T. F. Abdelzaher. A multi-frequency mac specially designed for wireless sensor network applications. ACM Transactions in Embedded Computing Systems, 9, 2010.