WLAN Channel Occupancy Modeling and Validation

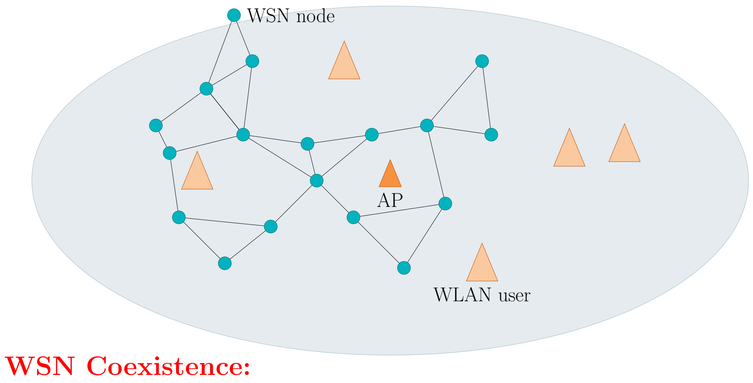
Ioannis Glaropoulos[1], **Viktoria Fodor**[1], **Alexandre Vizcaino Luna**[2], and **Maria Papadopouli**[2]

[1]Access Linnaeus Center, KTH Royal Institute of Technology, Stockholm, Sweden
[2]School of Electrical Engineering, KTH Royal Institute of Technology, Stockholm, Sweden

1 Introduction

1.1 Heterogeneous networks sharing the 2.4GHz ISM Band

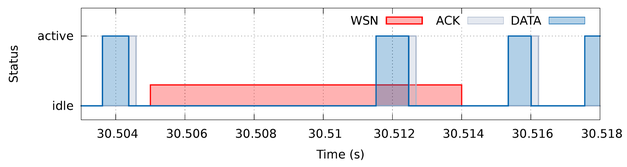
- **802.11x Networks (WLAN)**
  - Highly common
  - Radio Interface for powerful devices
  - Higher Tx- Power & Range
  - High Detection Sensitivity
- **Wireless Sensor Networks (WSN)**
  - Low Tx-Power
  - Low Detection Range
  - CPU constrained
  - Battery-powered



WLAN & WSN Coexistence:

- "blind" WLAN terminals do not detect ongoing WSN transmissions
- The mutual interference is **asymmetric** because of the different power levels
  - WSN performance degrades significantly; WLAN performance is hardly affected

1.2 The WLAN-WSN Coexistence Problem



WSN packets are usually too long to fit within the short WLAN idle periods

- Cognitive access mechanisms are essential
- The underlying WLAN **channel usage pattern** should be identified
- WSN transmission schemes should **adapt** to the undelying WLAN channel usage patterns

1.3 Aim of this work

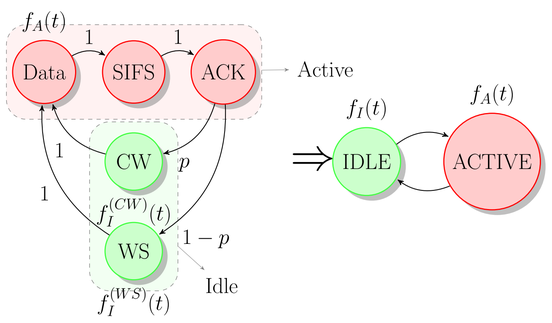
- **WLAN Channel Usage Modeling**
- **Validation of an Analytic WLAN Usage Model**

2 WLAN Channel Occupancy – Modeling and Estimation

- **WLAN spectrum activity prediction** – Derivation of a stochastic spatio-temporal model for WLAN *active* & *idle* channel periods

Global (Fully-observable) Activity Model: 2-state semi-Markovian system [1] - Models all activity in a single WLAN-AP area

- Active time (traffic-specific): $A \sim U(\tau_{\min}, \tau_{\max})$, $f_A(t) = \frac{1}{\tau_{\max} - \tau_{\min}}$
- Idle time (mixed distribution, with heavy-tail): $f_I(t) = p f_I^{\mathrm{CW}}(t) + (1-p) f_I^{\mathrm{WS}}(t)$
  - $f_I^{\mathrm{CW}}(t)$: Almost uniform short WLAN back-off periods
  - $f_I^{\mathrm{WS}}(t) = \frac{1}{\sigma}\left(1 + \frac{\xi x}{\sigma}\right)^{-\frac{1}{\xi}-1}$: Generalized Pareto distributed *white spaces*



Locally Observable Activity Model [2]

- Limited WSN sensing range → Clear Channel Assessment Zone (CCA)
- Partially observed WLAN load ($p_{\mathrm{CCA}} \in [0,1]$) → 3-state semi-Markovian model

  Correlation of local views decreases with sensor distance

- **Parameter Estimation**
  - Parameterizing the analytic functions, $f_A(t), f_I(t), f_{\tilde{I}}(t)$ based on samples obtained through channel sensing
    - Maximum Likelihood Estimation for $f_A(t), f_I(t)$ [Global View]
    - Laplace Transform-based algorithm for $f_{\tilde{I}}(t)$ [2] [Local View]

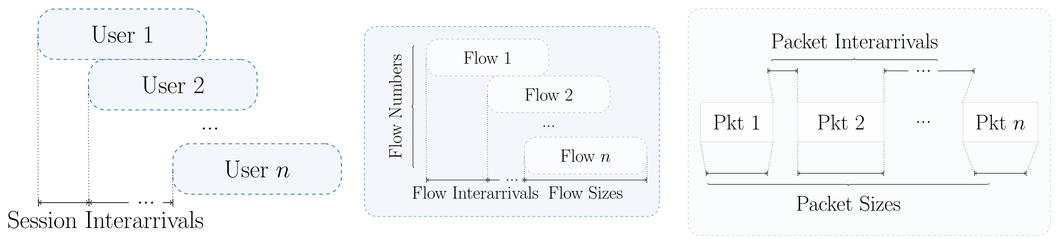
3 WLAN Occupancy Model Validation

3.1 Motivation

- Investigate **whether** and **when** the proposed semi-Markovian system is a realistic modeling option for the WLAN channel usage

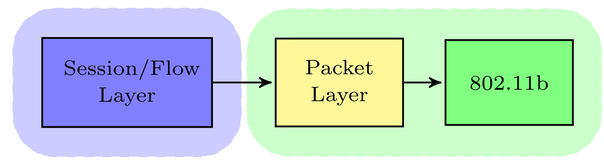
3.2 Multi-Layer WLAN Traffic Model

- A "Campus-WLAN" case-study [3]:
  - A measurement-based traffic workload model in a campus-wide WLAN
  - Multi-layer modeling of user behavior
    - Session- and Flow-level modeling
    - Flow characterization and packet-level modeling
- Statistical Modeling
  - Session Arrivals: Time-variant Poisson Process
  - Flow Inter-arrival times: Log-normal Process
  - Flow Number/Sizes; Bi-Pareto

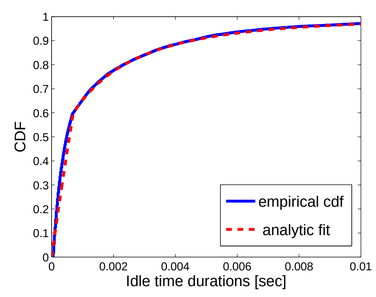


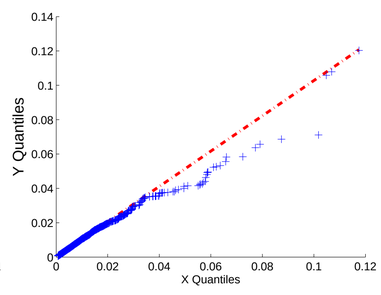
3.3 Simulation Methodology

- **Extensive** NS-miracle simulation study [4]
  - Idle sample series generation
  - $f_I(t)$: (ξ, σ, p) estimation applying MLE [2]
  - D-value-based evaluation of fitting quality, $D = \sup_n |F_I(t_n) - F_{Ie}(t_n)|$, (between the estimated and empirical idle period densities)

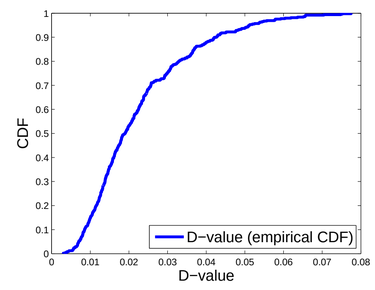


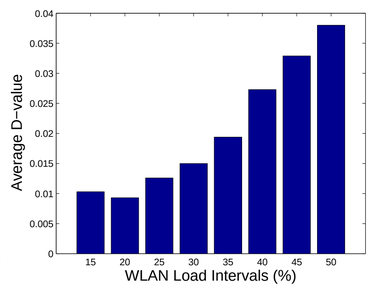
3.4 Evaluation Results



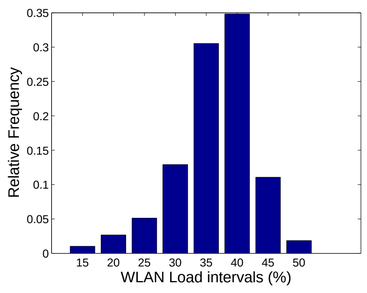


- One simulation run
  - $D = 0.021$
  - Fitting quality evaluated depicting the Q-Q plot





- Aggregate Statistics
  - A low D-value indicates high fitting quality
  - D-value increases with network *load* (percentage of time WLAN channel is busy)



- The cases of high channel load are, however, rare, based on the given traffic workload model
- The model sufficiently captures the statistics of the WLAN idle periods

4 Conclusions

- WLAN channel occupancy prediction is an essential mechanism for improving the communication performance of co-existing low-powered WSN networks
- The proposed semi-Markovian model is valid, unless the WLAN is highly loaded

References

[1] S. Geirhofer, L. Tong, and B. M. Sadler. Cognitive medium access: Constraining interference based on experimental models. *IEEE Selected Areas in Communications*, 26(1), 2008.

[2] M. Lagana, I. Glaropoulos, V. Fodor, and C. Petrioli. Modeling and estimation of partially observed wlan activity for cognitive wsns. In *IEEE Wireless Communications and Networking Conference (WCNC)*, pages 1526 –1531, april 2012.

[3] Félix Hernández-Campos, Merkouris Karaliopoulos, Maria Papadopouli, and Haipeng Shen. Spatio-temporal modeling of traffic workload in a campus WLAN. In *Proceedings of the 2nd annual international workshop on Wireless internet*, WICON '06, New York, NY, USA, 2006. ACM.

[4] Alexandre Vizcaino Luna. Characterizing WLAN channel occupancy for cognitive networking. Master's thesis, Royal Institute of Technology (KTH), July 2012.