Detecting 802.11 Wireless Hosts from Remote Passive Observations

Based on paper by
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Detecting 802.11 Wireless Hosts from Remote Passive Observations

(1)Introduction

(2)Extracting a Wireless Signature

(3)Experimental Scenario

- Spectral Analysis
- Sample Entropy

(4)Detection Algorithm

(5)Evaluation

(6)Conclusion

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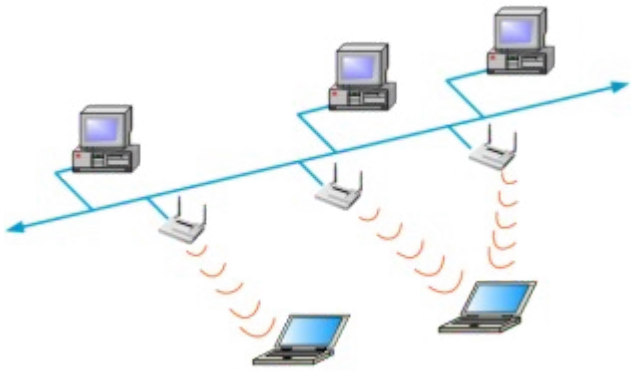
LANs in nowadays

- Hybrid local area networks
  - with wired and wireless clients
- Network access through 802.11
  - increased mobility
  - lower throughput, harder latency
  - unpredictable nature of the wireless medium



Chapter 1

Introduction

Aim of the research

- Characterizing and studying wireless traffic
- Highlighting essential differences and analogies with wire-line traffic
- Question:
  Are there any techniques to detect 802.11 wireless hosts?

Chapter 1

Introduction

Passive identification

- They looked into the problem of passive identification of wireless clients
- Observing at a location inside a network where a diverse set of client traffic is aggregated
- The observed clients use TCP/UDP protocols

Chapter 1

Introduction

What can we expect?

- “Uncertainty” of wireless traffic
  - unique signature
  - distinguish wireless form wired
- Depend on:
  - channel access mechanism
    - shared radio medium
  - channel conditions
  - link quality

Chapter 1

Introduction

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Chapter 2

Extracting a Wireless Signature

The aim

- Capturing the physical layer “signature” in a traffic flow through the inspection of the packet interarrival times
- We exploit two main features that a-priori differentiates wired from wireless access:
  - the unpredictability of the wireless medium
  - the impact of the 802.11 medium access control (MAC) mechanism

Conjecture

Chapter 2

Extracting a Wireless Signature

- Conjecture:
  These mechanisms are bound to random delays in the transmission of packets from a wireless host

- Shared radio medium
  - Packet loss, retransmit packet, delaying the packet delivery at the receiver
  - Client needs to contend for channel access

Measurement and problems

Chapter 2

Extracting a Wireless Signature

- Create constant bit rate (CBR) flows
  - using wired medium
  - using wireless medium
- Problems with the purely periodic data
  - highly loaded host
  - network congestion
  - multiplexing
- Not periodic traffic stream (like VoIP)
- They used
  - controlled experiments
  - periodic traffic

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Generating traffic

Chapter 3

Experimental Scenario

- Generating traffic flows from wired and wireless clients to destinations outside the LAN
- *tg* - Traffic Generator Tool
  - http://www.postel.org/tg/
- UDP/TCP traffic streams
  - UDP: CBR of 1.6 Mbps
    - 1000 byte packets sent every 5 ms
  - TCP: bulk transfer of large files
- Test uses ethernet interface and 802.11b wireless NIC
- The collection point is at the edge of the private LAN

Wireless experiments 1

Chapter 3

Experimental Scenario

- Good
  - 1 client
  - good location
  - no channel contention
  - signal level: -43 dBm
- G-Cong
  - 3 clients
  - good locations
  - contention for channel access
  - signal level: -43 dBm

Wireless experiments 2

Chapter 3

Experimental Scenario

- Bad
  - 1 client
  - bad location
  - no channel contention
  - signal level: -65 dBm
- Bad-Cong
  - 3 clients
  - bad locations
  - contention for channel access
  - signal level: -65 dBm

Spectral Analysis

Chapter 3

Experimental Scenario

- The purpose of this analysis is to investigate how the physical layer characteristics influence the explicit or implicit periodicity of a traffic flow
- Discrete Fourier Transform (DFT)
  - Fast Fourier Transform (FFT)
  - Processing of packet interarrival times
- Process of packet arrivals:

$$x[n]=\begin{cases}1, nT_0 \leqslant t_{arr} < (n+1)T_0 \\ 0, elsewhere\end{cases}$$

Fourier transformed signal

Chapter 3

Experimental Scenario

- Discrete time interval: $[nT_0, (n+1)T_0]$
  - overlapping problem
- Packet arrivals are never spaced by less than 20μs
  - T_0 := 20μs
- Resolution of frequency domain:
  - $f_0 = 1/T_0$ (= 50 KHz)
- Observation window: NT_0
- Fourier transformed signal:

$$X[kf_0] = \frac{1}{N}\sum_{n=0}^{N-1} x[nT_0]e^{-j2\pi\frac{nk}{N}}$$

Cumulative Power Spectrum

Chapter 3

Experimental Scenario

- DFT power spectrum P[n]:

$$P[kf_0] = |X[kf_0]|^2$$

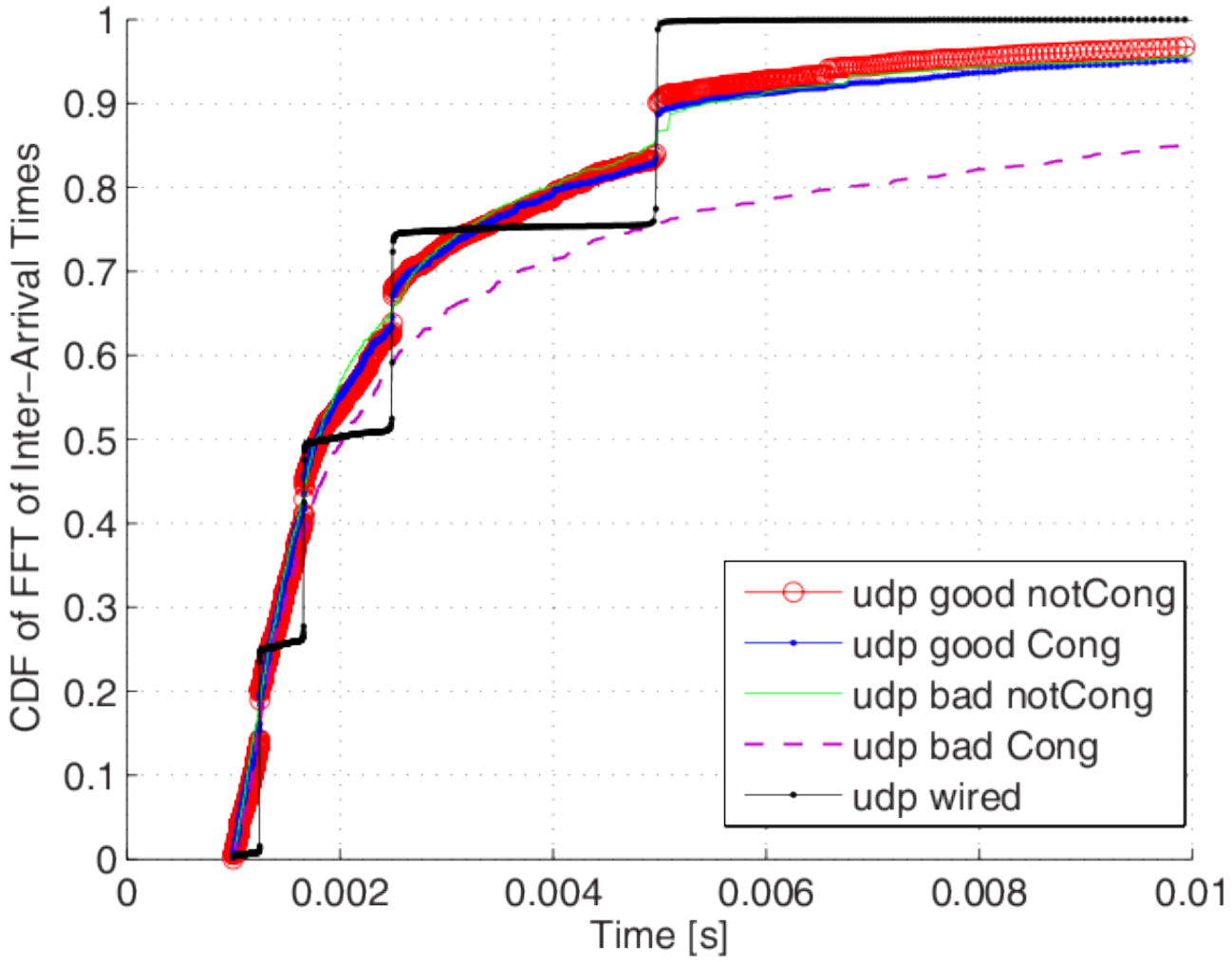
- Cumulative Power Spectrum (CPS) is use to compare different power spectra
- It is normalized to the total power of the signal as

$$C(n) = \frac{\sum_{k=0}^{n} P[kf_0]}{\sum_{k=0}^{N-1} |X[kf_0]|^2}, 0 \leqslant n < N$$

CPS of UDP wired and wireless CBR flows are computed

Chapter 3

Experimental Scenario



CPS of TCP wired and wireless CBR flows are computed

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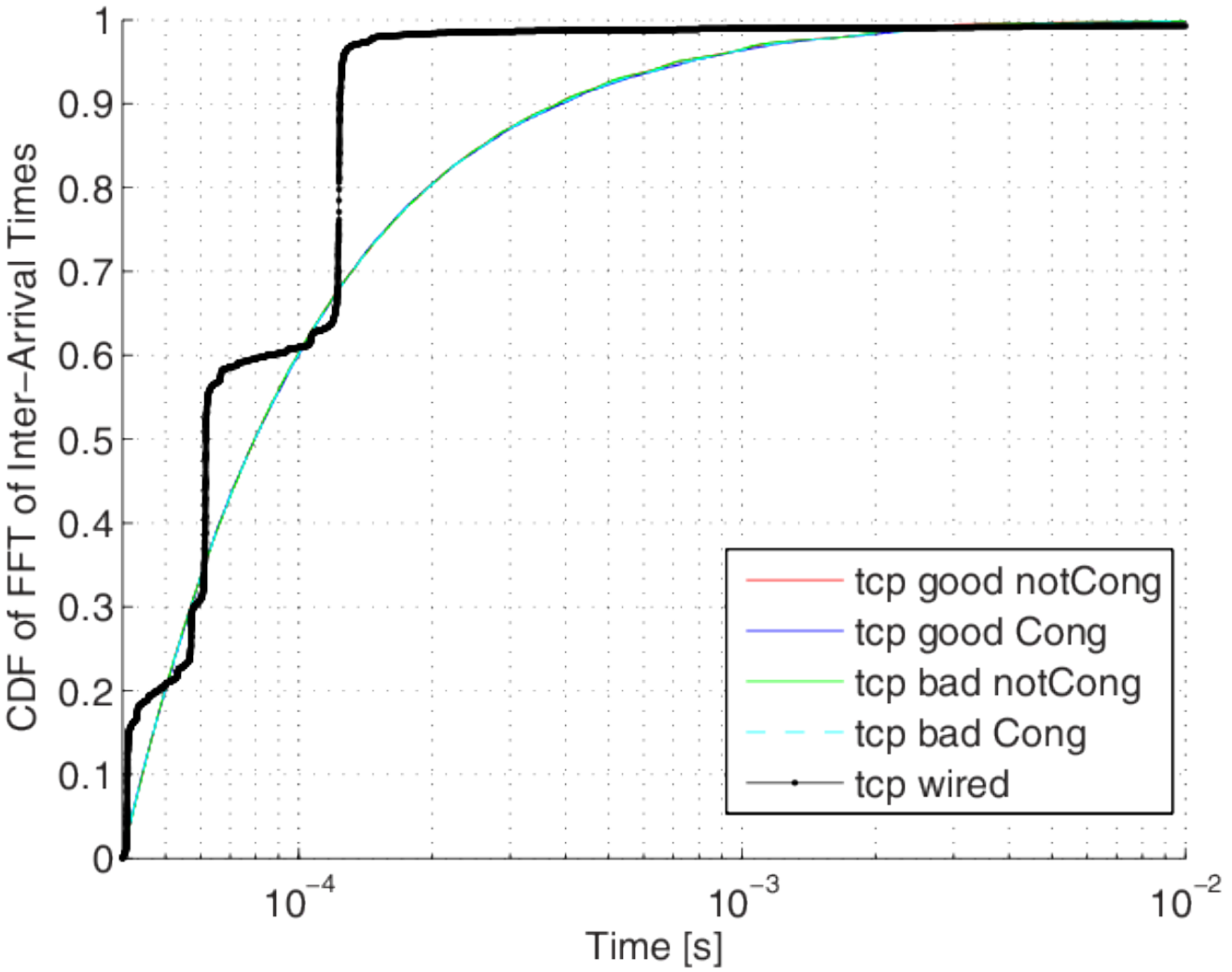
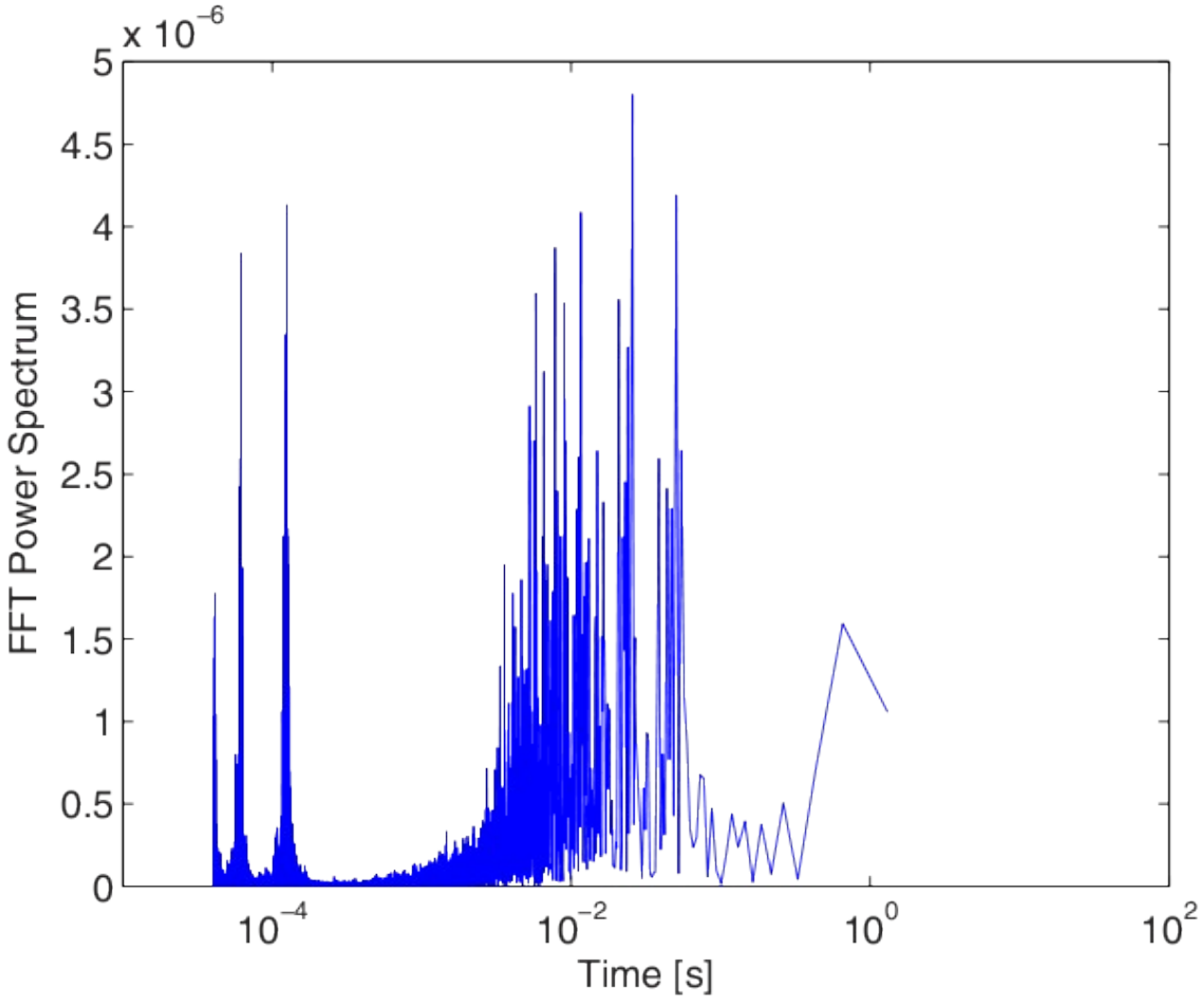


DFT Power Spectrum of TCP (wired)

Chapter 3

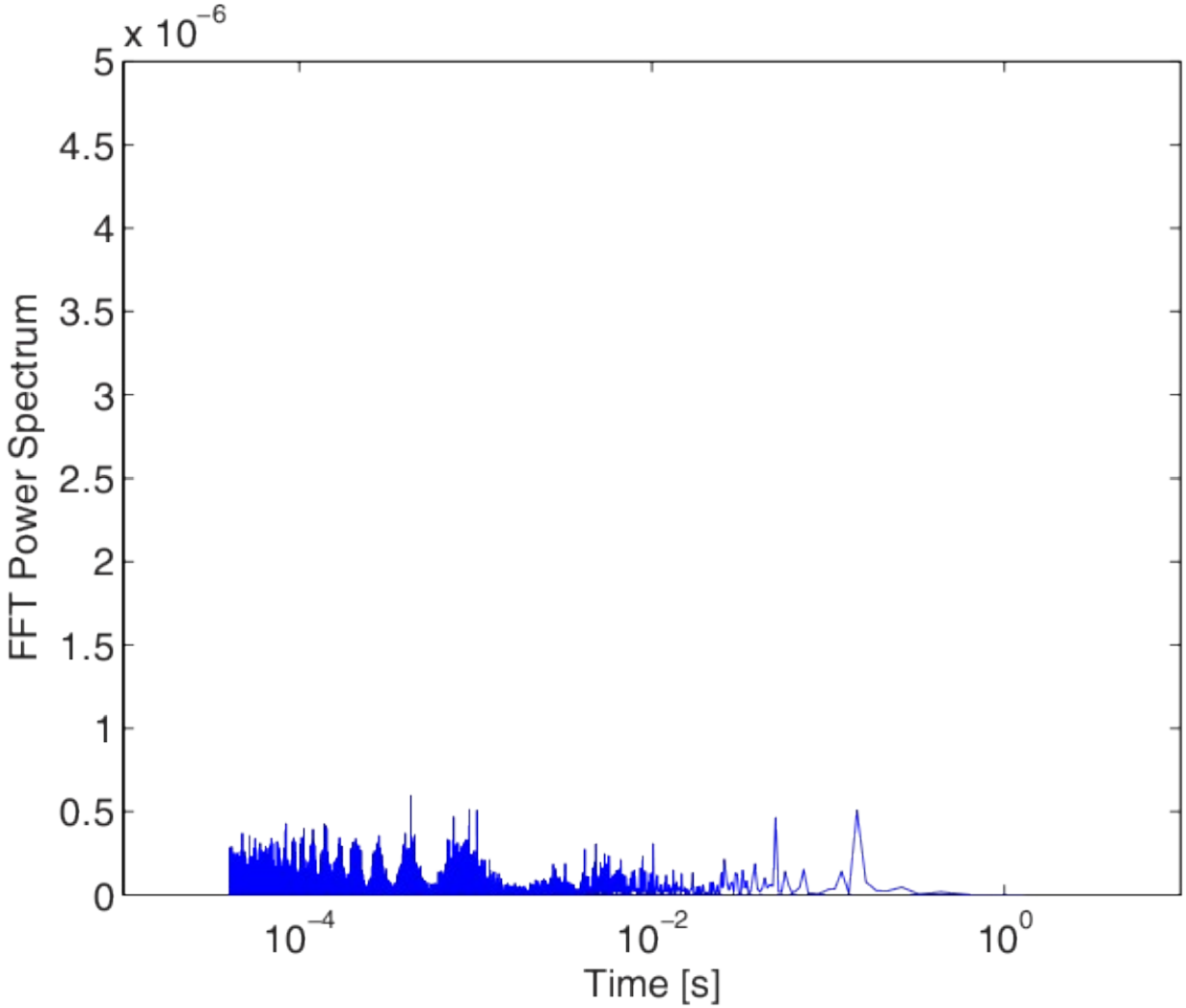
Experimental Scenario



DFT Power Spectrum of TCP (wireless)

Chapter 3

Experimental Scenario



Behaviour of TCP traffic

Chapter 3

Experimental Scenario

- Original traffic stream is not periodic
  - periodicity distortion
- Analysing those parts of the traffic streams where packets are sent in a back to back fashion
  - network effects are more visible
- Dropping all the big interarrival times exceeding a certain threshold, T_{RTT}.
- Choosing a big T_{RTT} := 10 ms

Sample entropy

Chapter 3

Experimental Scenario

- DFT methodology
  - computationally expensive
  - difficult to be incorporated within an automated algorithm
- Empirical entropy
  - because of empirical distributions
- Empirical entropy of interarrival time distribution:

$$H(x) := -\sum_{x_i \in X} p(x_i) \log_2 p(x_i),\ p(x_i) = \frac{m_i}{m}$$

Empirical entropy

Chapter 3

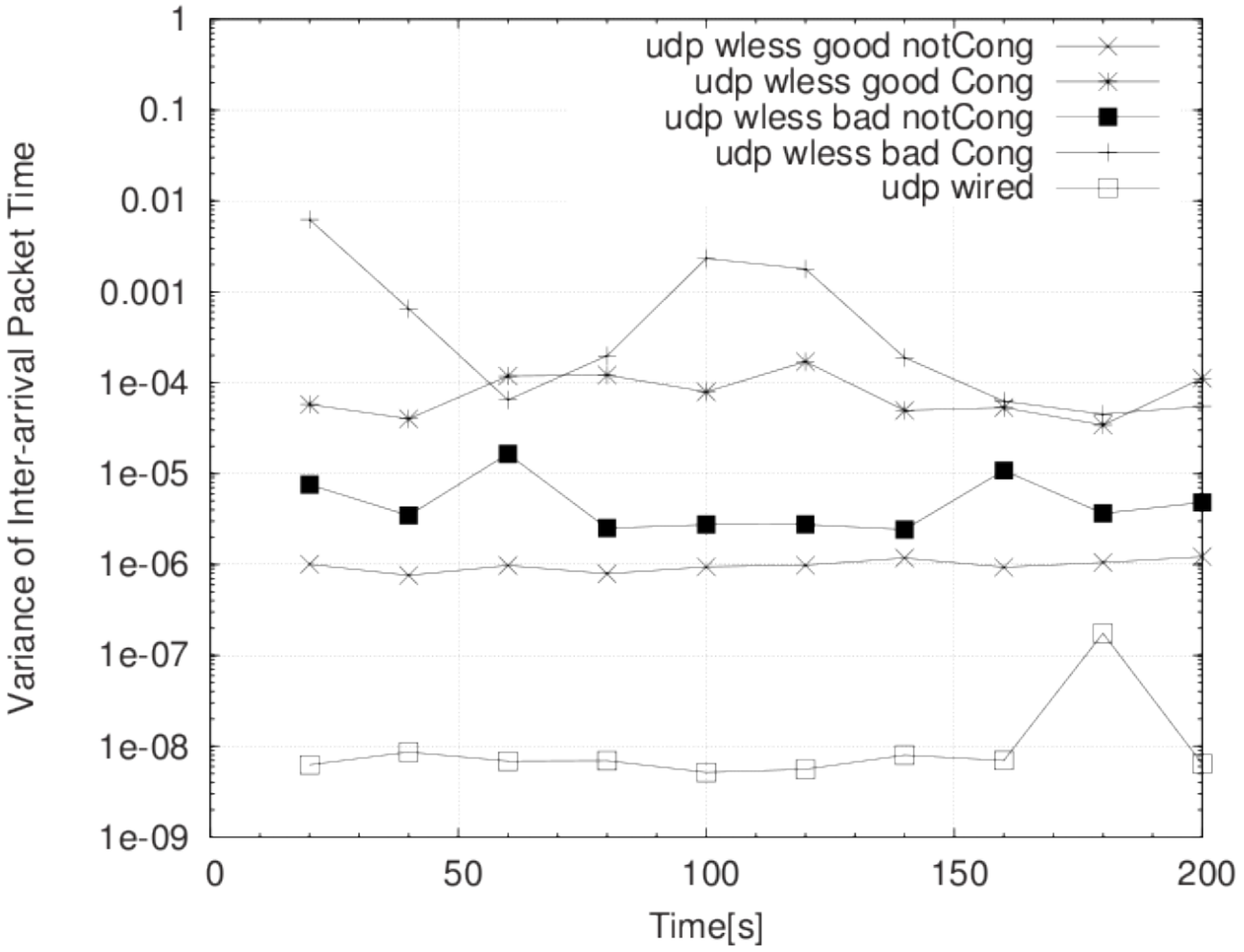
Experimental Scenario

- Empirical entropy values computed on the same distribution can be different
  - depend on time scales to discretize the sample
- Bin size to compute Probability Mass Function (PMF): 100μs
- Computing the entropy of the PMF of packet interarrivals across time

Variance of interarrival packet time (UDP)

Chapter 3

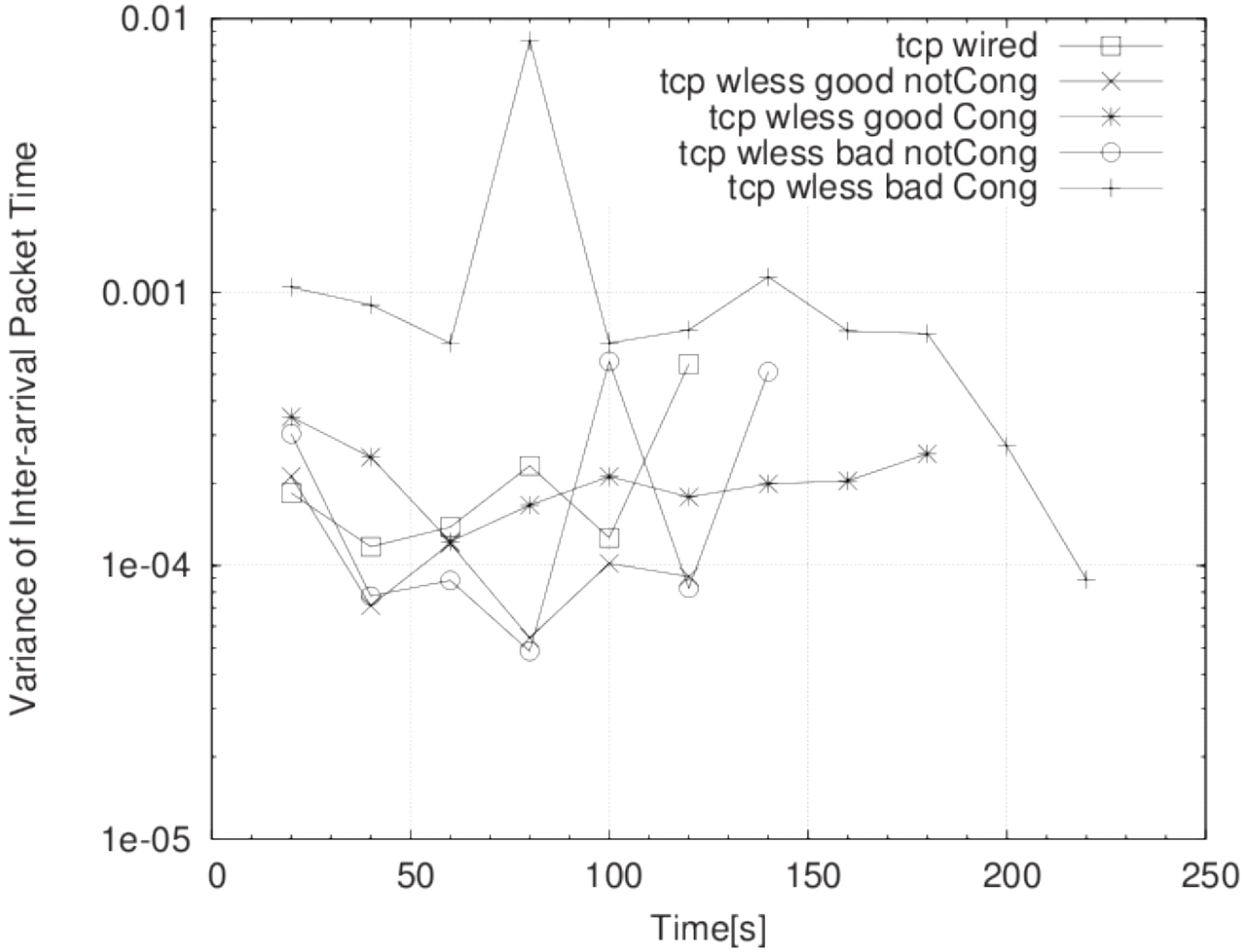
Experimental Scenario



Variance of interarrival packet time (TCP)

Chapter 3

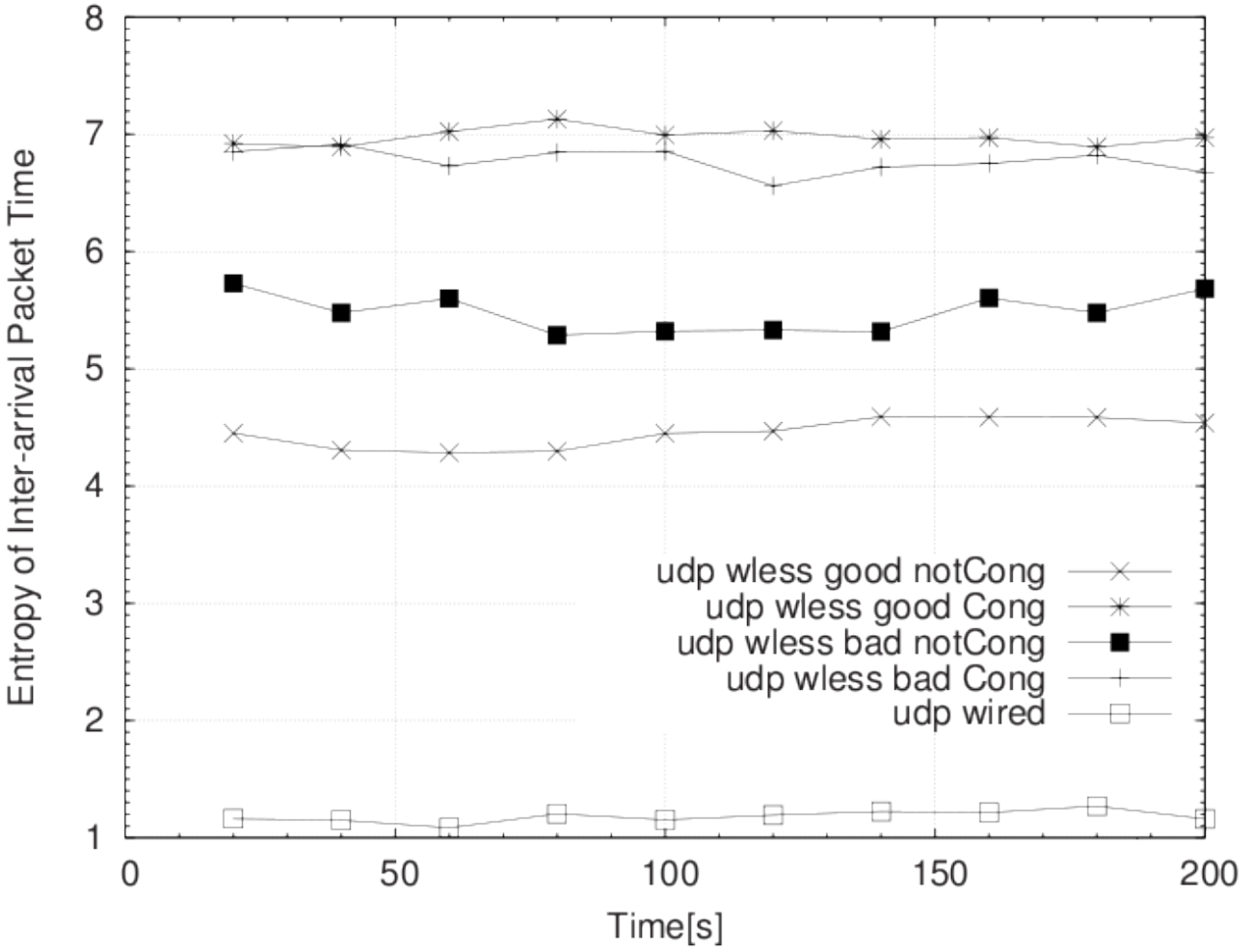
Experimental Scenario



Entropy of interarrival packet time (UDP)

Chapter 3

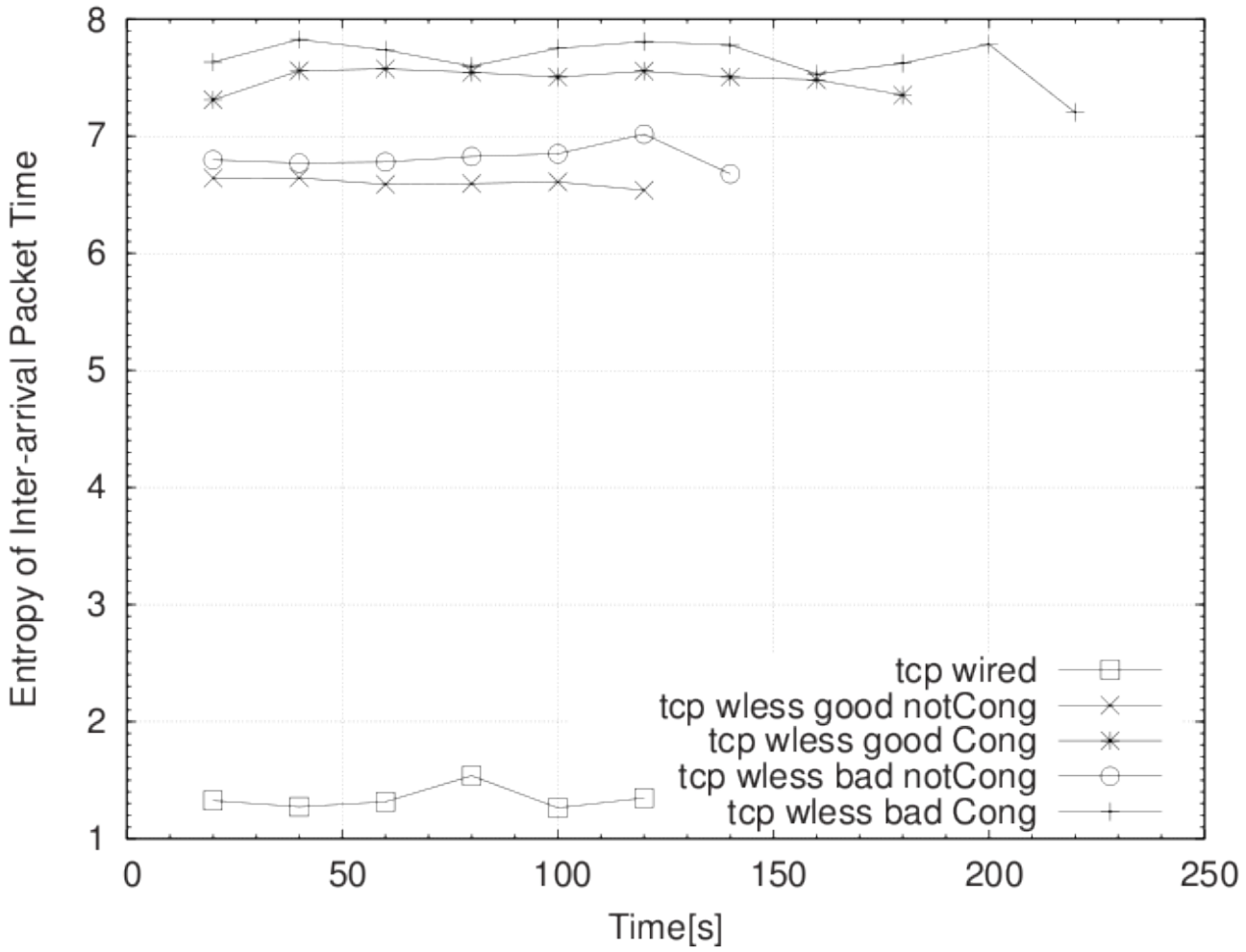
Experimental Scenario



Entropy of interarrival packet time (TCP)

Chapter 3

Experimental Scenario



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Algorithm to classify

Chapter 4

Detection Algorithm

- Within each IP-source set, 5-tuple flows are then isolated
- Interarrival times between consecutive packets are computed and then filtered: only those, falling below T_{RTT}, are kept
- Computing:
  - the empirical entropy $H_{IP,}$ evaluated on the whole IP-source aggregated traces
  - the empirical entropy of the largest 5-tuple flow of each IP-source trace, $H_{IP,5}$
- Variation of Entropy: $\Delta H = H_{IP} - H_{IP,5}$

Pseudo code of the algorithm

Chapter 4

Detection Algorithm

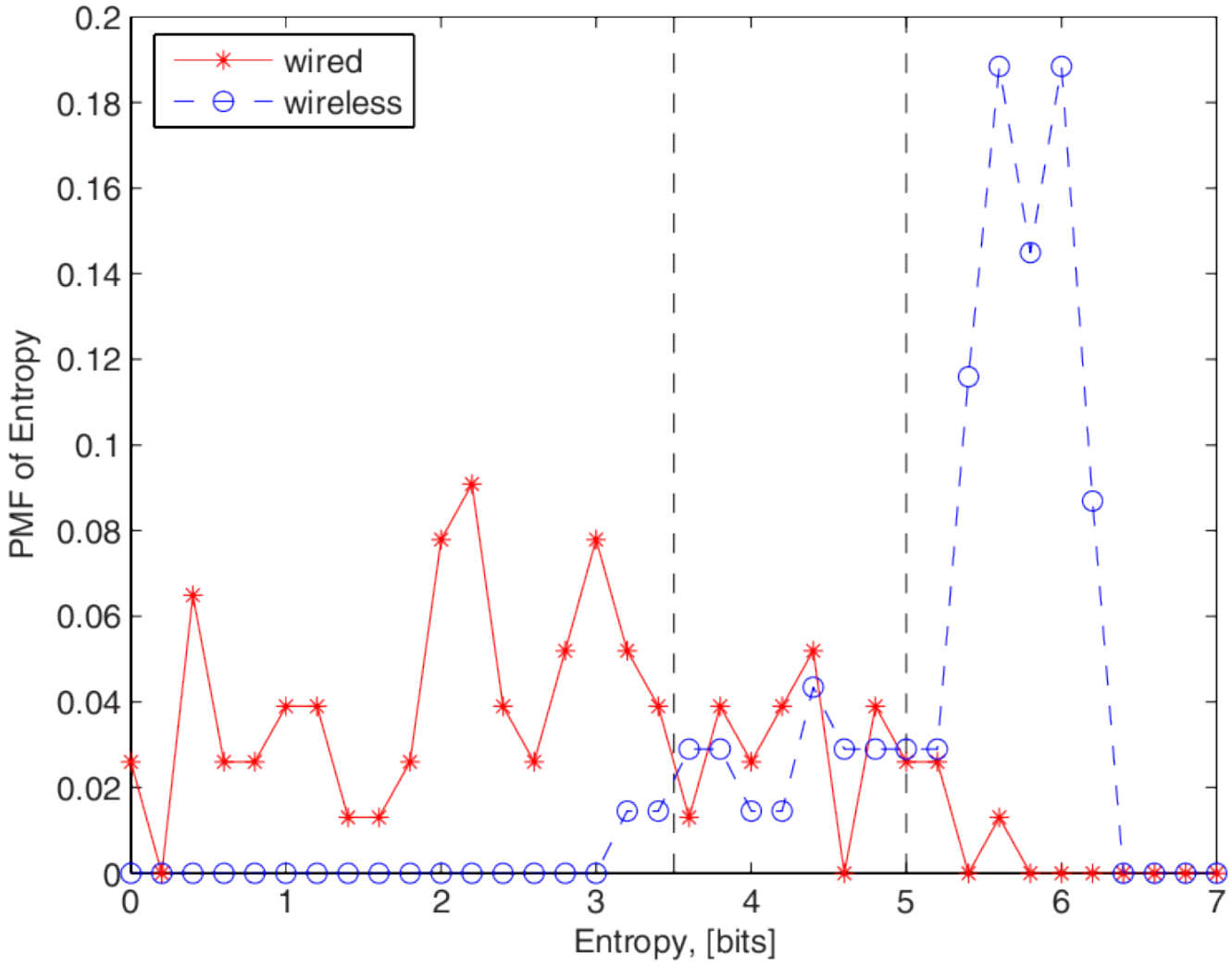
```
If H_IP ≤ H_lower
        then the host is wired
 else if H_IP ≥ H_upper
        then the host is wireless
 else if H_lower < HIP < H_upper
        if ΔH ≥ ΔH_THR
                then the host is wired
        else if ΔH ≤ ΔH_THR
                then the host is wireless
```

- H_{lower} = 3.5 bits
- H_{upper} = 5 bits
- H_{THR} = 0.5 bit

Probability Mass Function of Entropy

Chapter 4

Detection Algorithm



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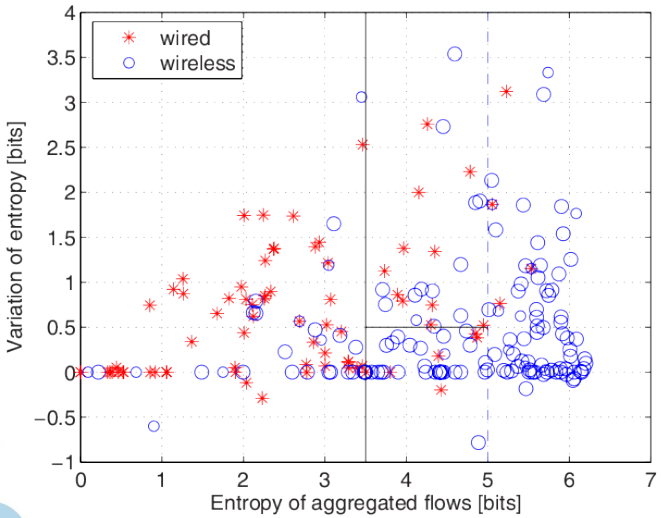
Evaluation

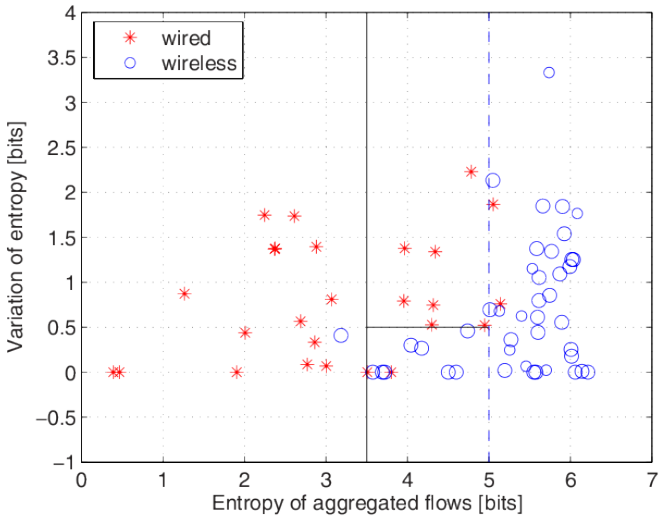
- Measured on 93 hosts in a laboratory
  - 27 WLAN hosts

Chapter 5

Evaluation



(a) Full datasets



(b) $Interarr > 200$

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Related works

- Bayesian inference algorithm
  - estimating and classifying whether TCP flows have traversed an 802.11 WLAN
  - time intervals occurs between TCP-ACK pairs and infers the connection type of a user
  - identification is possible only for clients that are employing the TCP protocol
  - making an inefficient use of traces

Chapter 6

Conclusion

Bayesian Inference Algorithm vs. Presented Algorithm

- Considers inter-packet pairs
  - so it is faster
- UDP and TCP
  - with time distance below 10ms

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Conclusion

Conclusion

- I have presented a method to classify wired and wireless hosts only based on passive traffic observations at a remote location
- The accuracy error reaches 1%-6%
- In the future this methodology will be tested on larger datasets

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