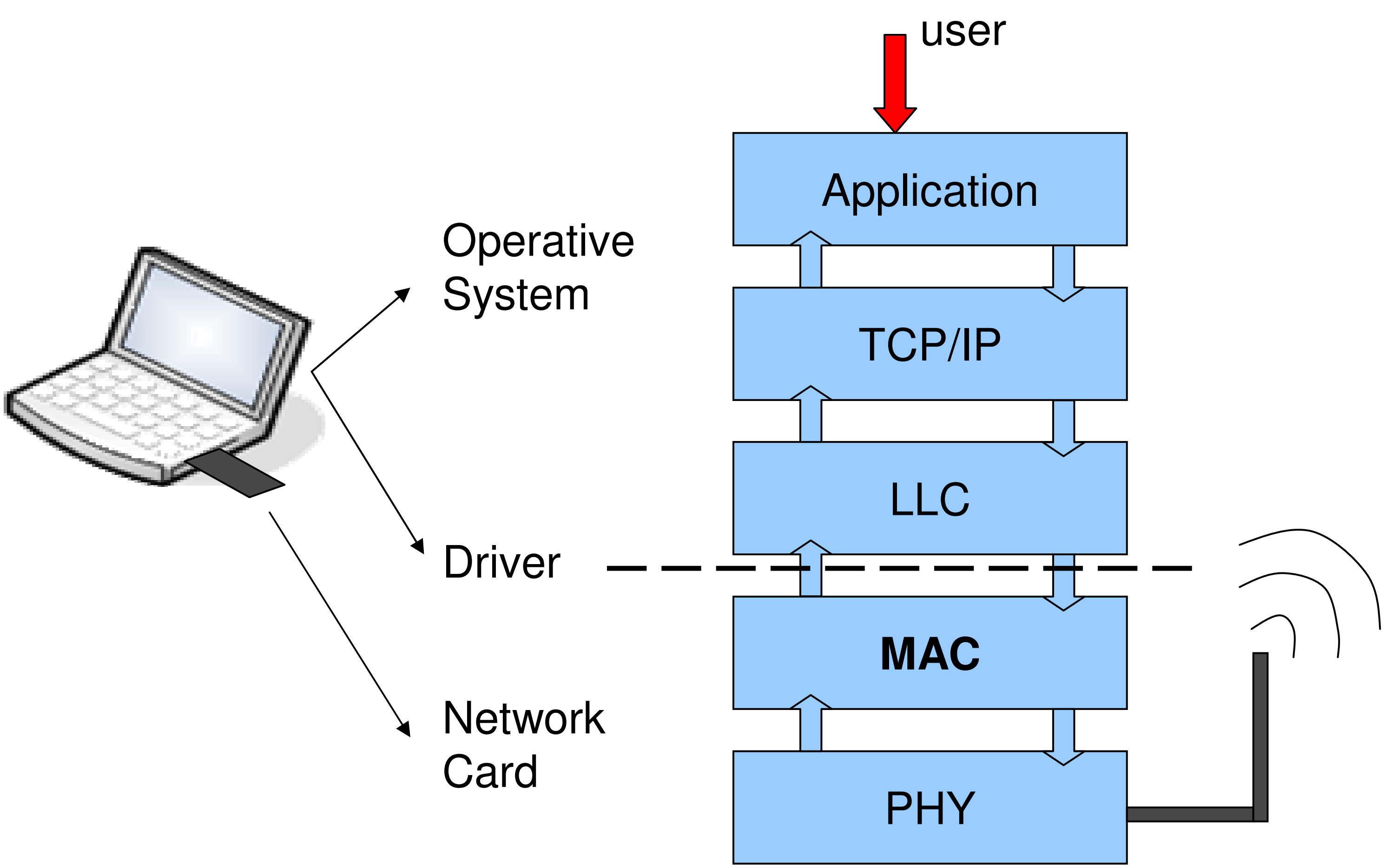
3. The wild world of WLAN

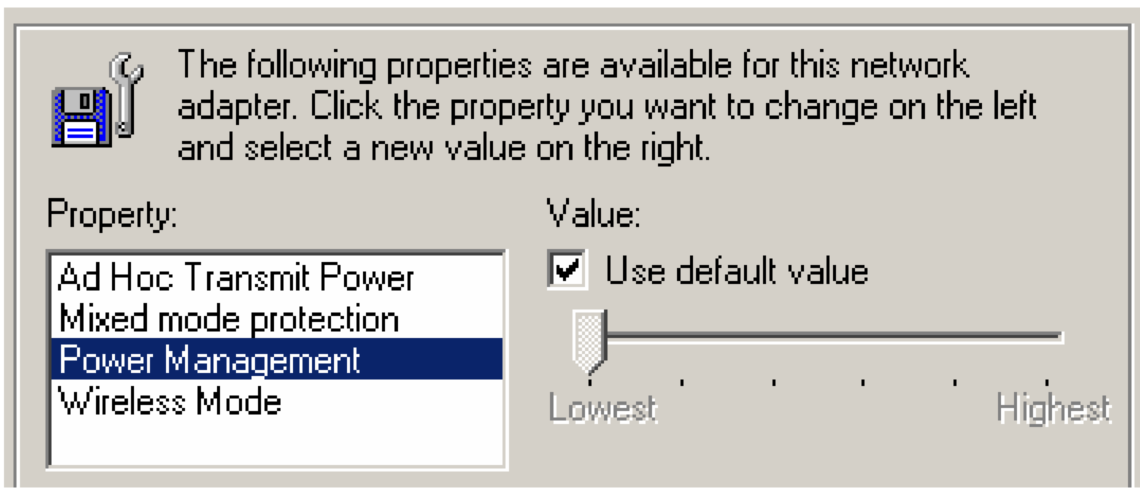
From theory to practice



User perspective: card settings

The user cannot access directly the lower stack layers, but can read/set parameters according to the driver interface, such as transmission channel, RTS threshold, transmission power..

EXAMPLE: Intel-Centrino under WinXP



User perspective: card performance

The user cannot see directly what happens on the radio channel, but it can notice the number of packets successfully received/transmitted (i.e. the throughput) at the application layer (e.g. iperf)

Typical performance measurements (saturating the transmission buffer):

1) Maximum achievable throughput when the station transmits alone
2) Bandwidth repartition with other contending stations

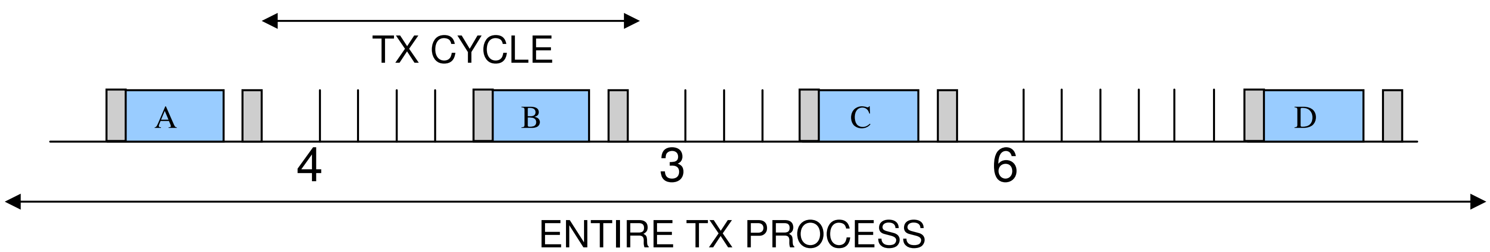
*Both the expected figures can be evaluated analytically as a function of the **packet length** and of the number of **competing stations** [1]*

```
C:\iperf>iperf -c 192.168.0.1 -i 1 -u -t 4 -b 3M
------------------------------------------------------------
Client connecting to 192.168.0.1, UDP port 5001
Sending 1470 byte datagrams
UDP buffer size: 8.00 KByte (default)
------------------------------------------------------------
[1916] local 147.46.251.223 port 2790 connected with 192.168.0.1 port 5001
[ ID] Interval       Transfer     Bandwidth
[1916]  0.0- 1.0 sec   368 KBytes  3.01 Mbits/sec
[1916]  1.0- 2.0 sec   366 KBytes  3.00 Mbits/sec
[1916]  2.0- 3.0 sec   366 KBytes  3.00 Mbits/sec
[1916]  3.0- 4.0 sec   366 KBytes  3.00 Mbits/sec
[1916]  0.0- 4.0 sec  1.43 MBytes  2.99 Mbits/sec
```

the ideal case

Max Throughput (1)

- Suppose to have just a single station, with a never empty queue
- Each transmission is originated after a backoff counter expiration (no delay due to the driver which forwards the packets to the network card)
- Since no collision is possible, and no channel error is considered, each backoff is extracted in the range [0, CW_{min}]

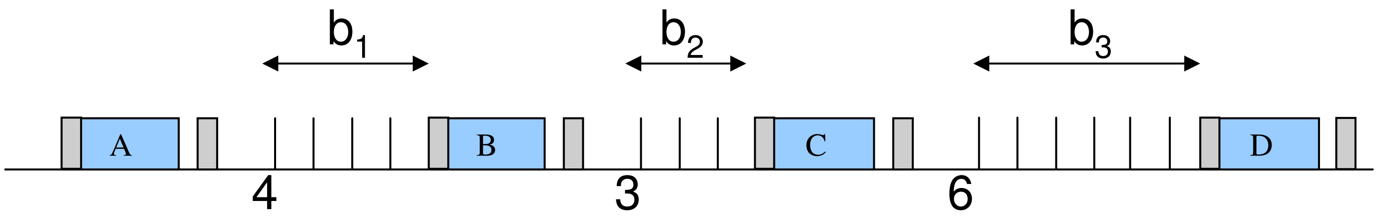


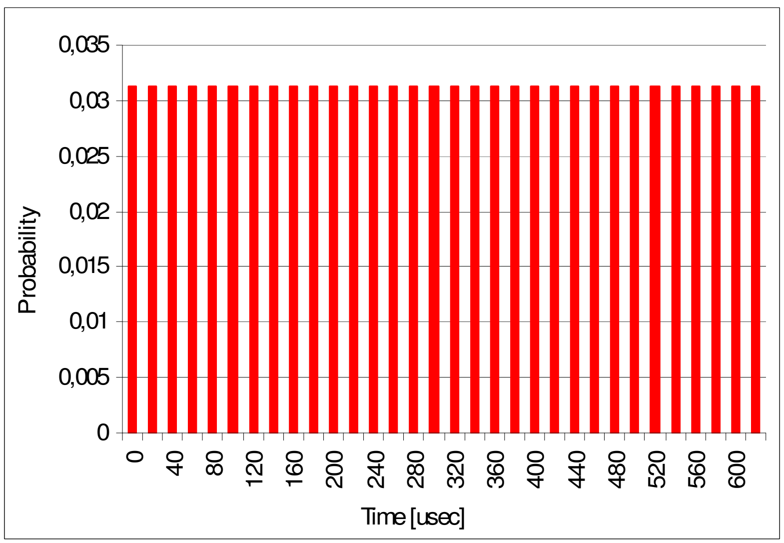
- Different transmission cycles on the channel, composed of:

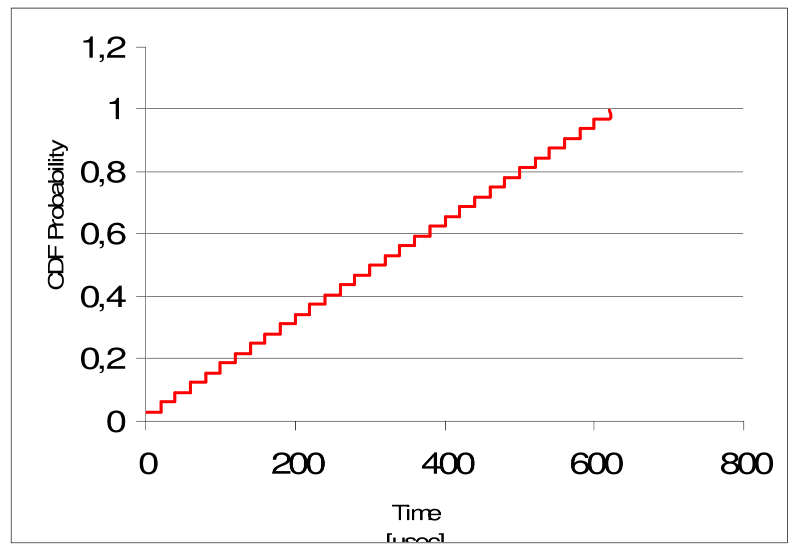
  1) frame transmission time, which depends on the MSDU size, including headers and ACKs;

  2) random delay time, which depends on the backoff extraction.

Inter-Frame Spaces (IFS)

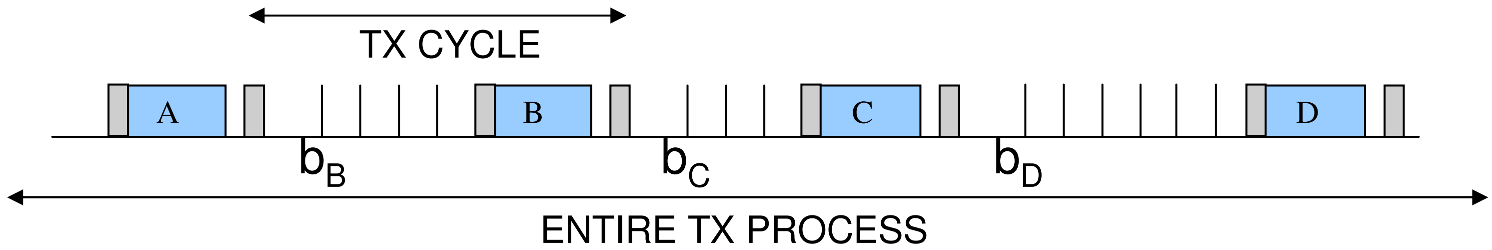






In absence of collisions and frame corruptions, b_i belong to a uniform distribution between [0, CW]T_{slot}, with a step cumulative distribution

Max Throughput (2)



- ➔ **From the throughput definition:** $$S = \frac{\sum P_i}{\sum \left(T_{FRAME_i} + b_i\right)}$$

- ➔ **From Renewal Theory:** $$S = \frac{E[P]}{E[T_{FRAME}] + E[b]}$$

- ➔ **In the case of fixed packet size, given CW$_{min}$:** $$S = \frac{P}{T_{FRAME} + \frac{CW_{\min}}{2} T_{slot}}$$

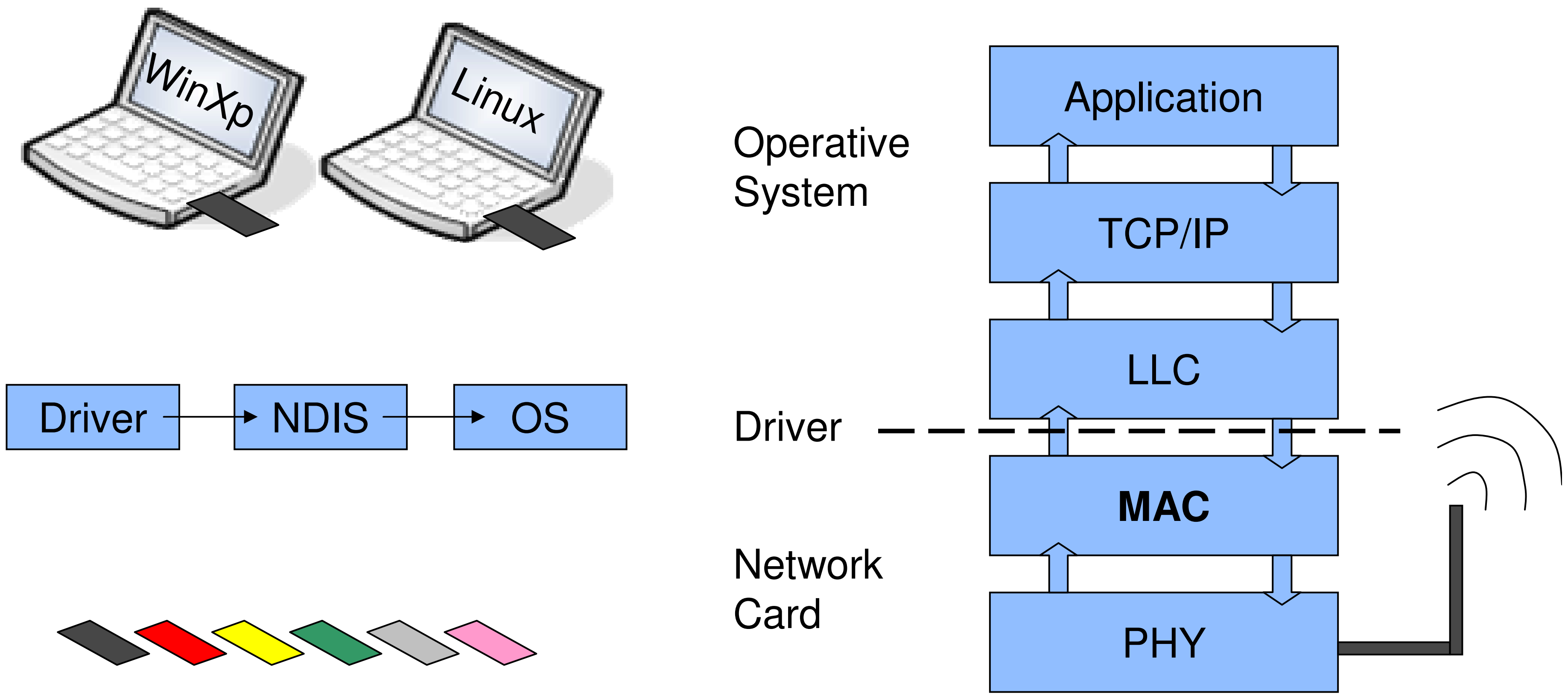
- ➔ **The result can be extended accounting for the number n of contending stations [1], each of which receives the same ratio S/n of the total throughput**

the actual world:
the user perspective

Commercial cards under test

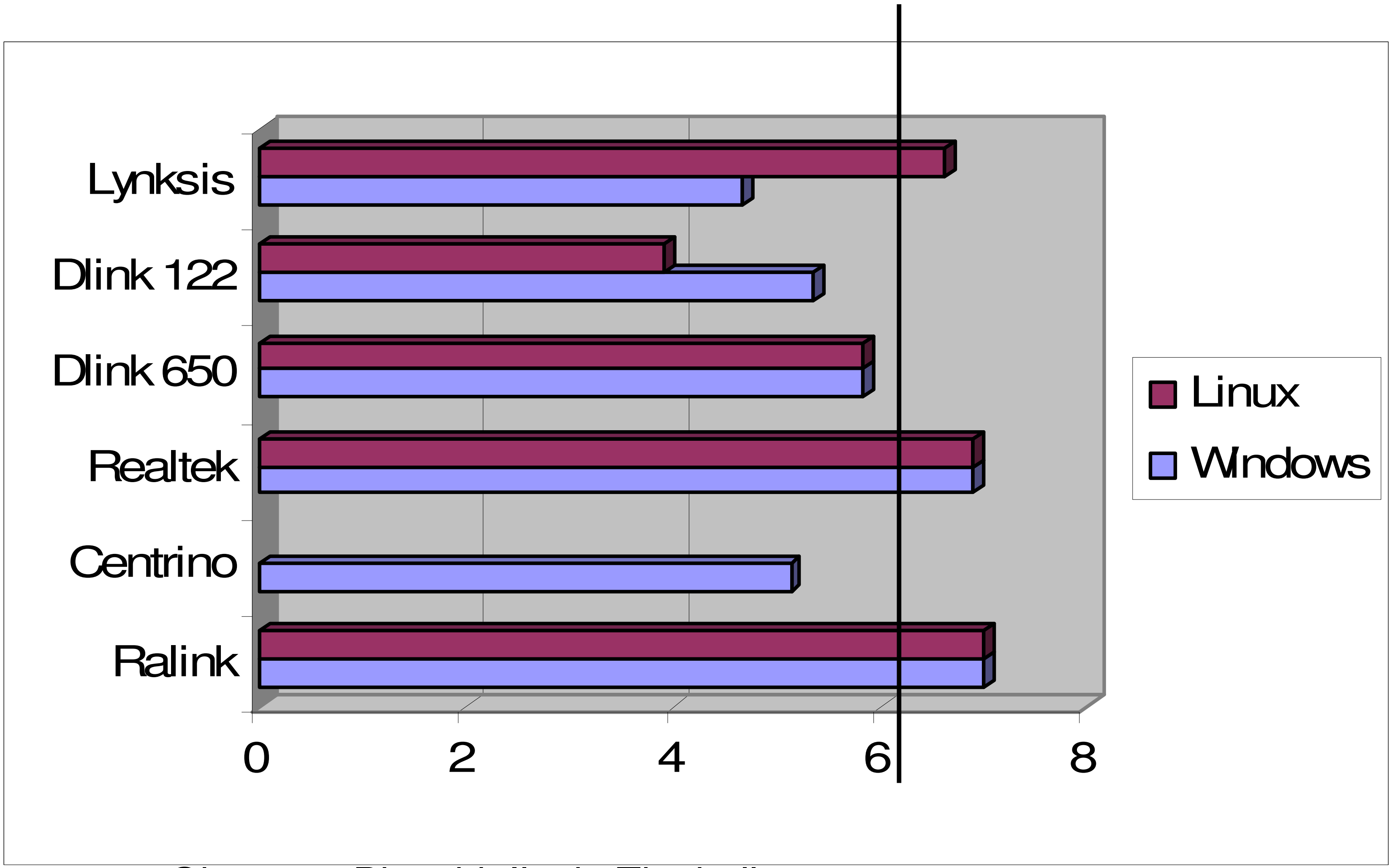
NIC	Chipset	Host Interface
Dlink DWL-650	**Intersil PRISM II**	**PCMCIA**
Dlink DWL-122	**Intersil PRISM II**	**USB 1.0**
Linksys WPC54G	**Broadcom**	**PCMCIA**
INTEL Centrino	**INTEL 2200BG**	**MiniPCI Compliant**
Digicom Palladio	**Realtek RTL8180**	**PCMCIA**
ASUS WL-107g	**Ralink RT2500**	**PCMCIA**

Complete Test Suite



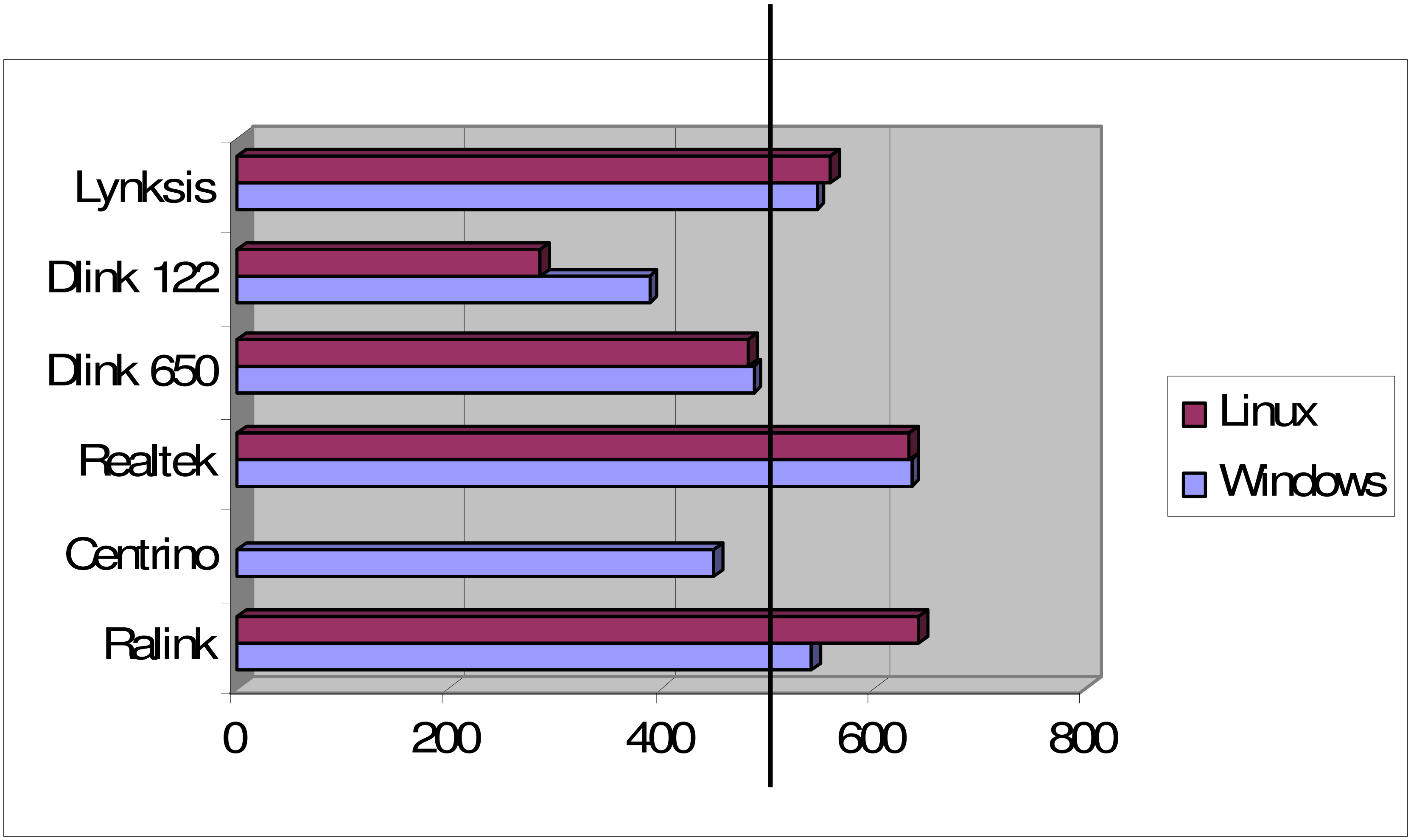
Max Throughput Spread (1)

(Payload =1470 byte, Thr expected = 6.1Mbps)

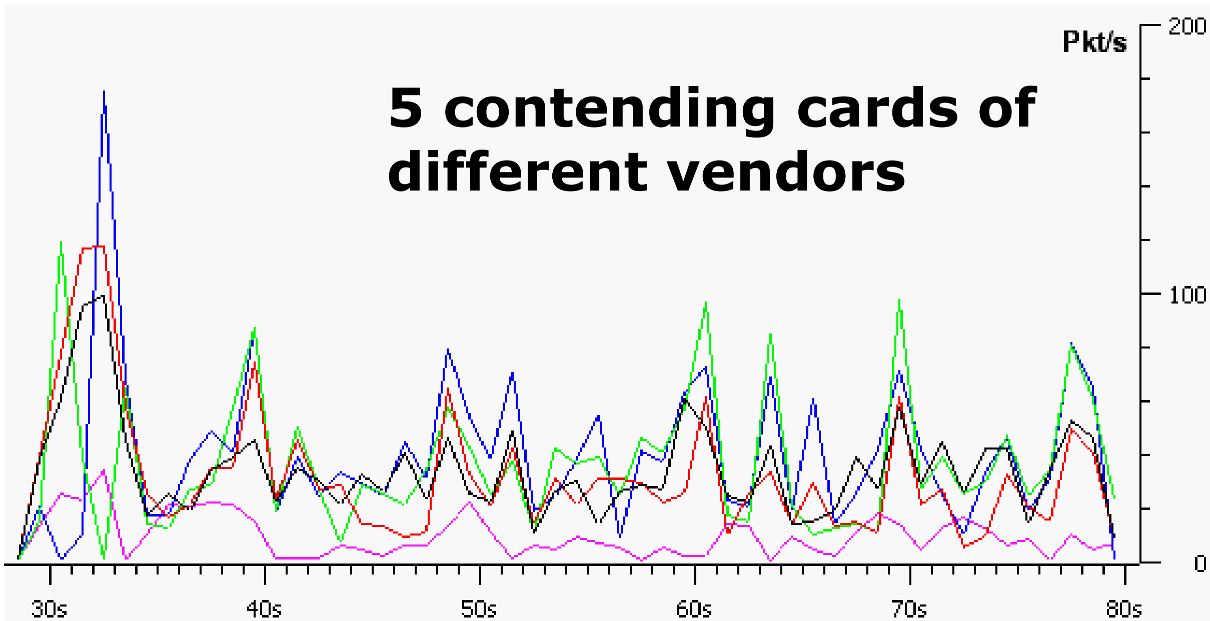


Max Throughput Spread (2)

(Payload =80 byte, Thr expected = 447 kbps)



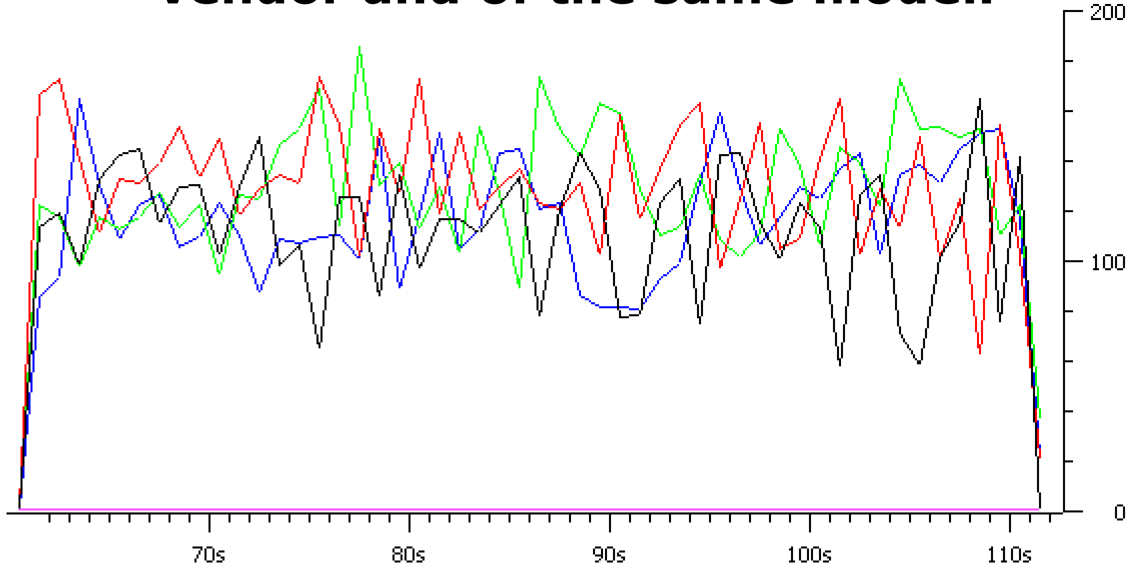
Bandwidth repartition (1)



- **lack of fairness;**
- **Time-varying aggregated throughput**

Bandwidth repartition (2)

4 contending cards of the same vendor and of the same model.



- **Good level of long-term fairness**
- **Constant aggregated throughput.**

What conclusion?

- ➔ **Are the differences due to the propagation conditions of each station?**
  - ⇨ We repeated our experiments in different laptop positions, in indoor/outdoor, in a semi-anechoic room.
- ➔ **Are the differences due to other external (i.e. not related to the card) factors?**
  - ⇨ We used the same laptop in all the experiments; some results do not depend on the OS; but.. who knows??

With user-side analysis it is not possible to distinguish between:

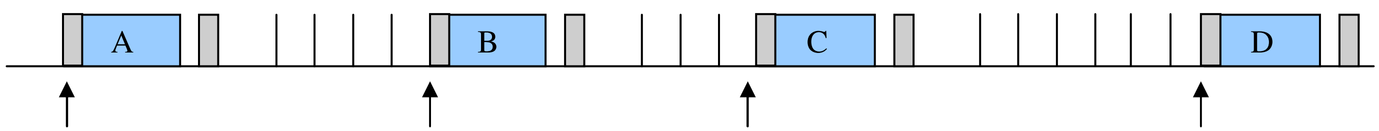
→*not-standard card behavior* (MAC operations)

→*implementation limits* (hardware/firmware, drivers, interfaces).

the actual world:
the radio channel analysis

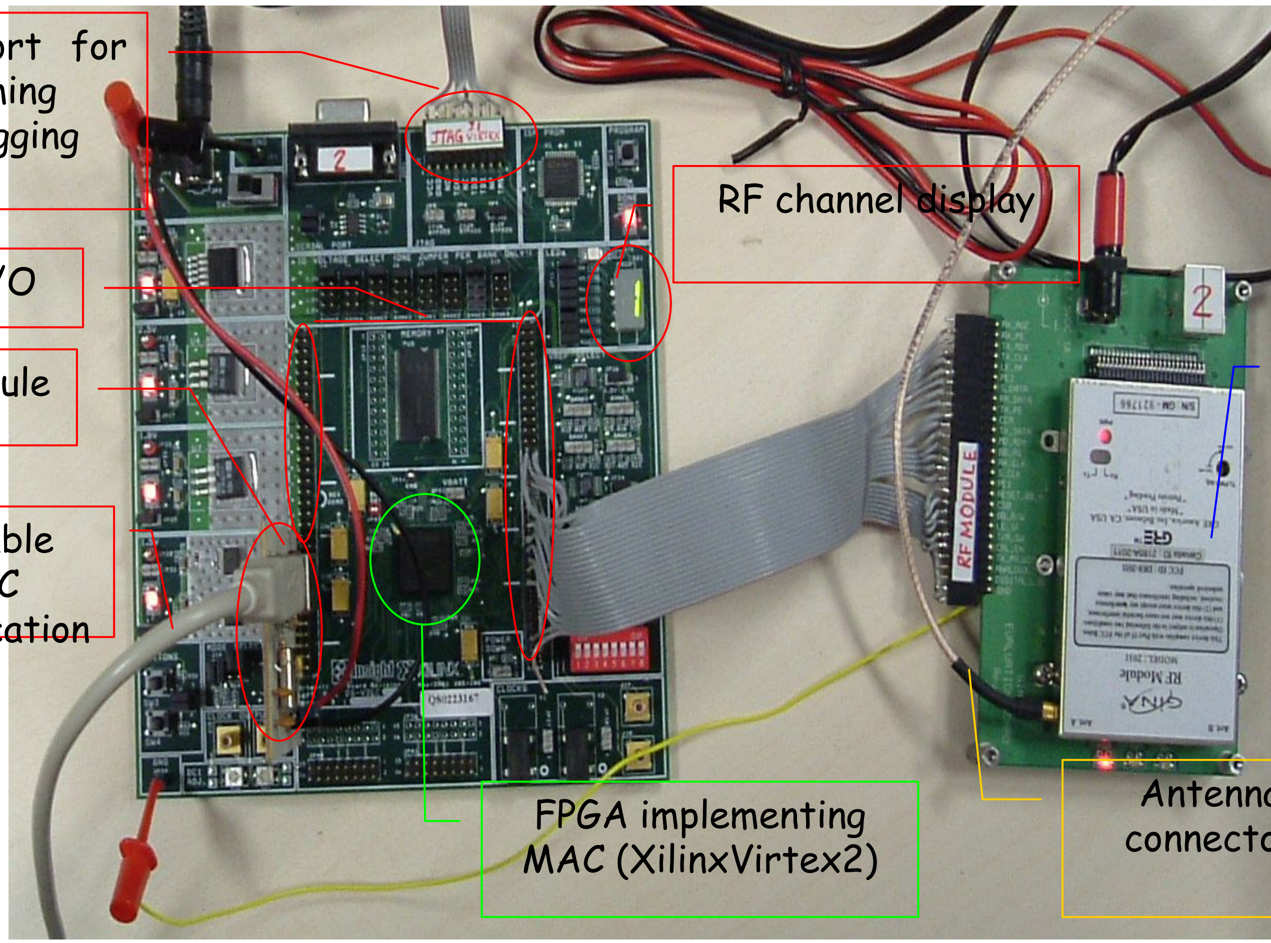
How to look at the channel status?

- **Some drivers allow to read the packet reception times, from which the IFS could be derived..**
  - inaccurate time scale
  - inaccurate estimation of the starting of the reception (the IFS times waste a few tens of usec)

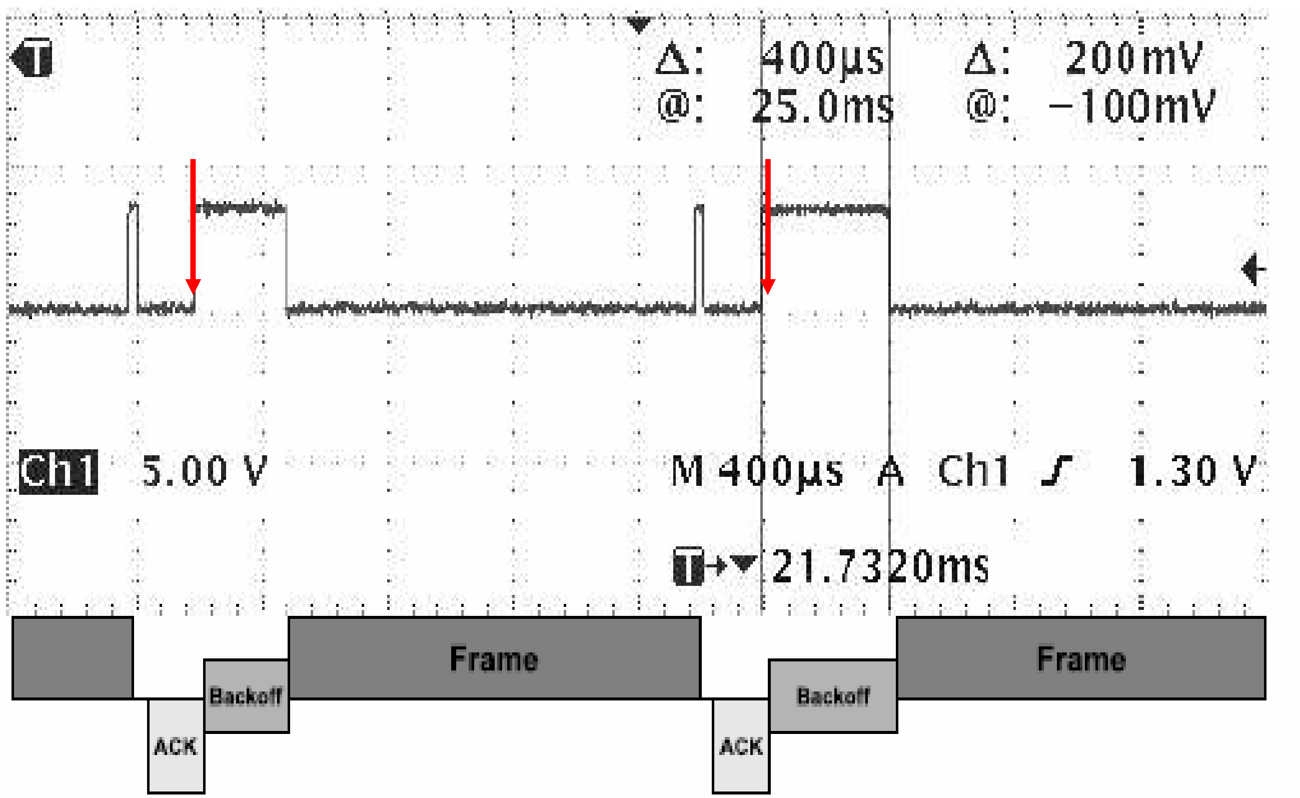


- **We should access the Carrier Sense signal of a monitor card, for recognizing channel activities/inactivities on a digital oscilloscope**
  - **Use of our custom-made card as a channel status reader (but much more!)**

MAC Programmable board: RUNIC



A PHY layer sniffing example

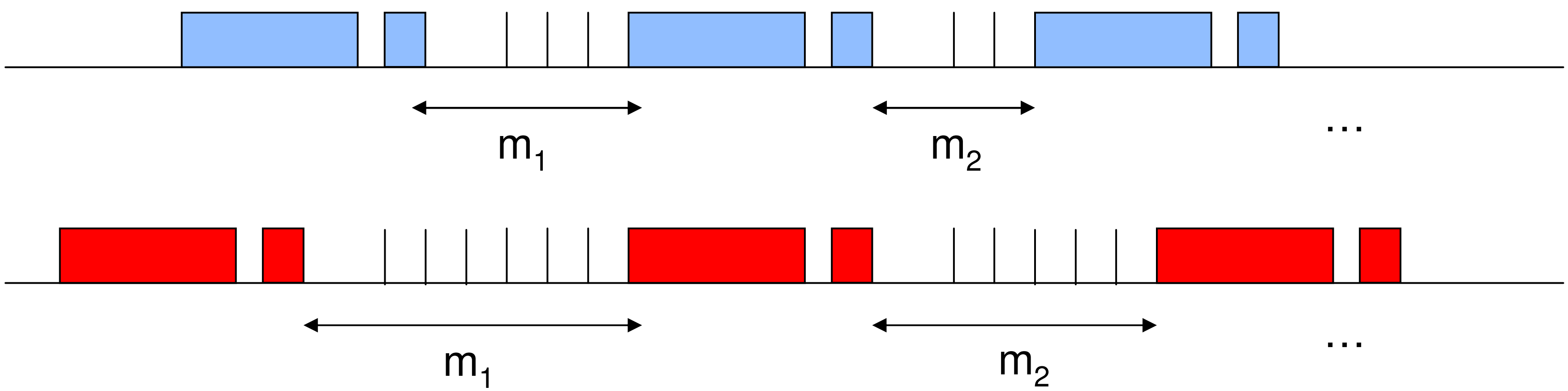


For accuracy purposes, times are read at the busy/idle transition (the idle/busy transition has some random delays)

Channel status analysis

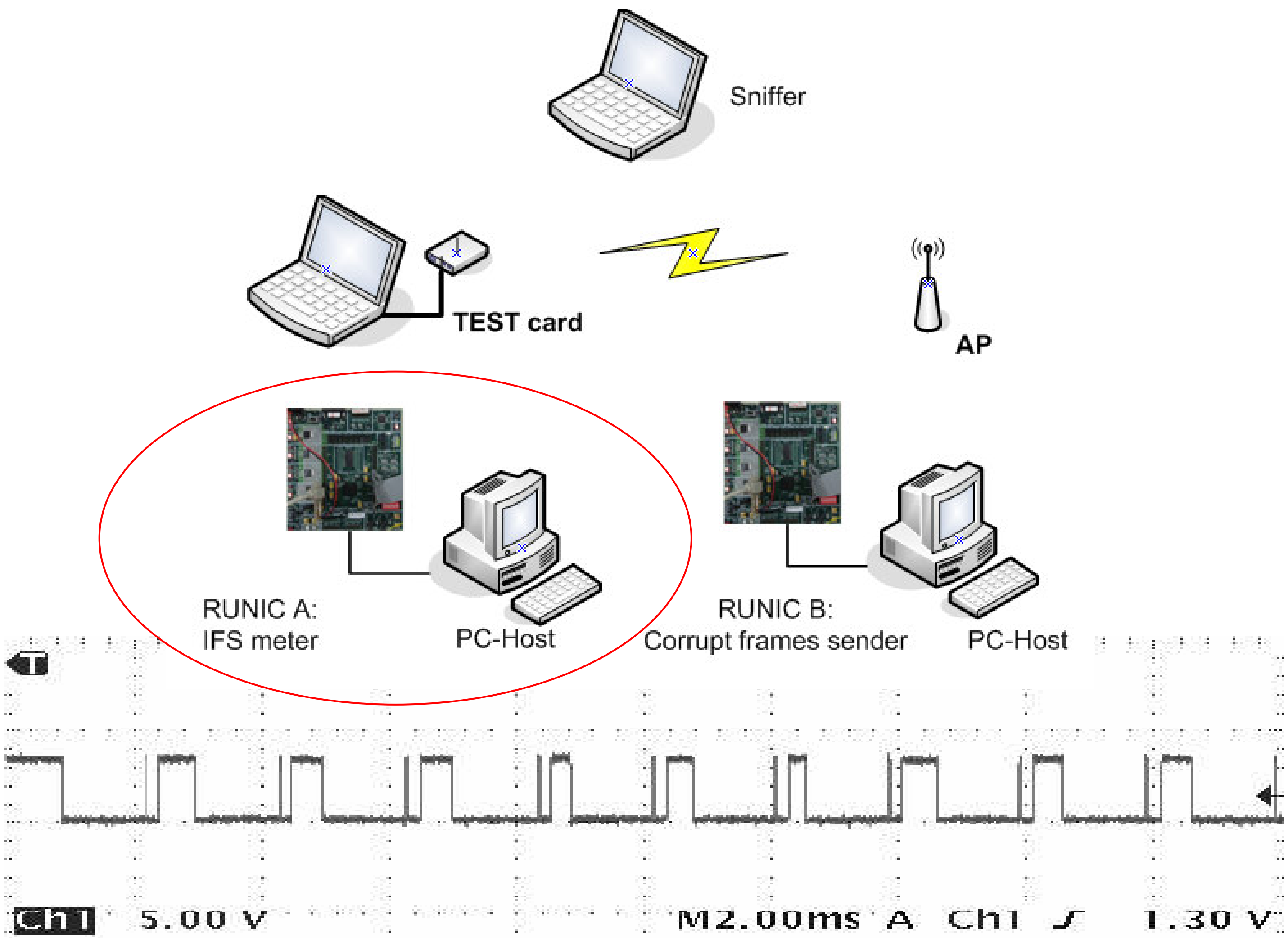
Monitoring of the PHY channel activity when a single test-card transmits continuously

The Inter-Frame-Space statistics allow to indirectly characterize the MAC behavior of the cards



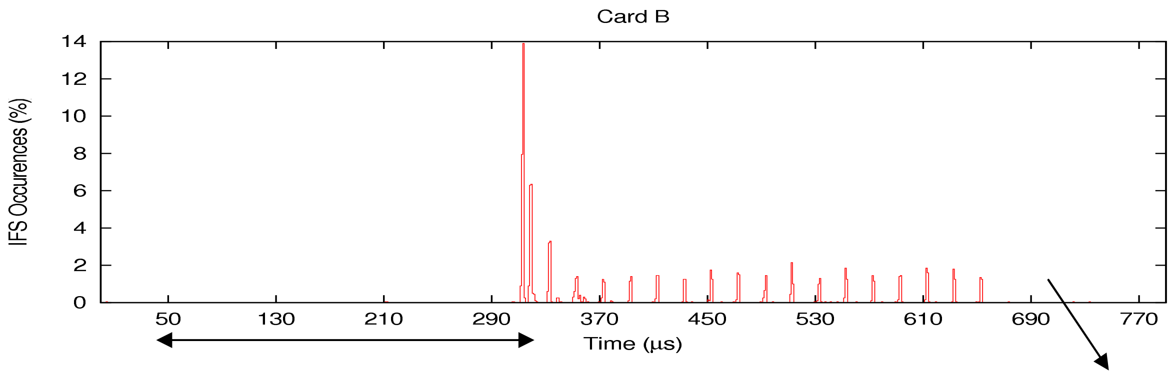
The measures are collected through the carrier-sense signal of our custom-made 802.11 card

Testbed Description



Backoff Analysis

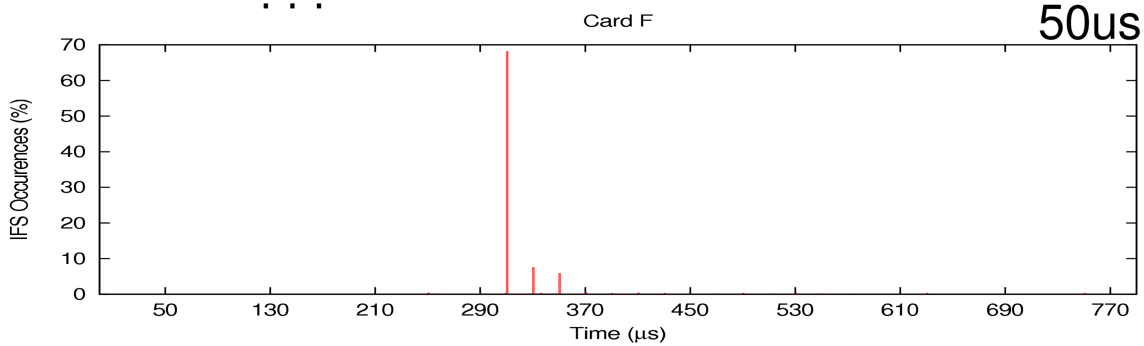
Centrino



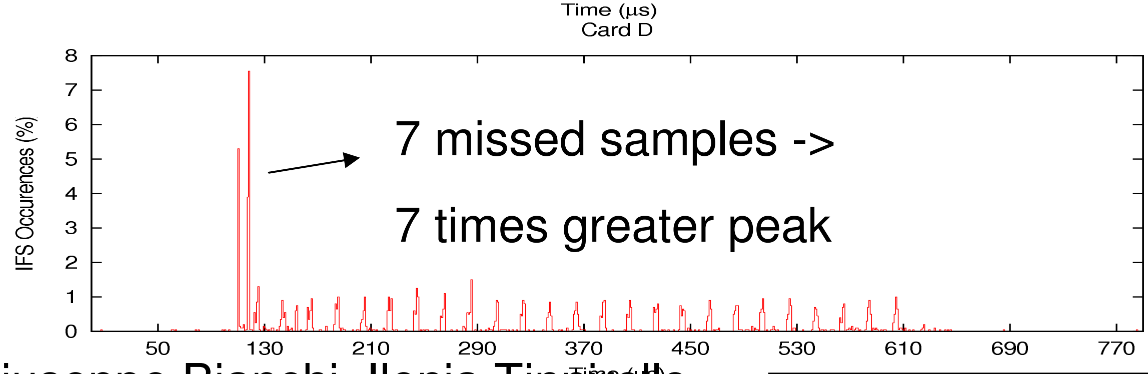
???

50us+20us*31=670us

Cisco

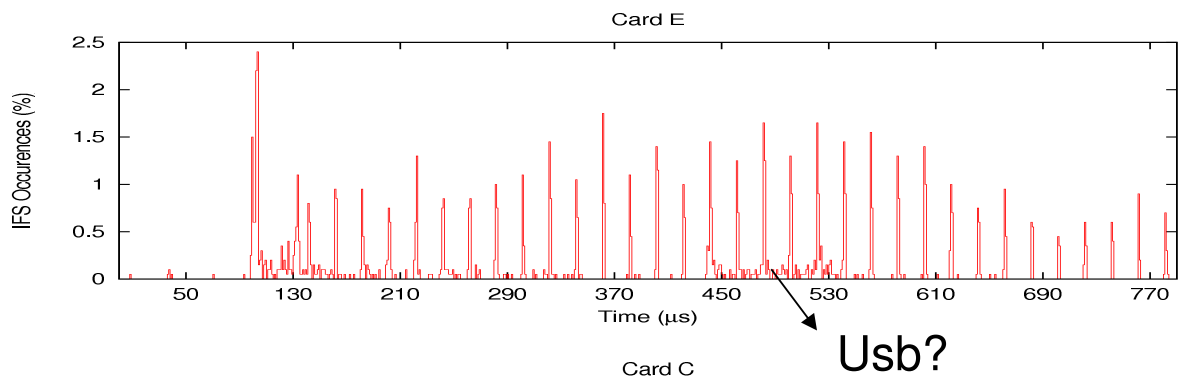


DWL650

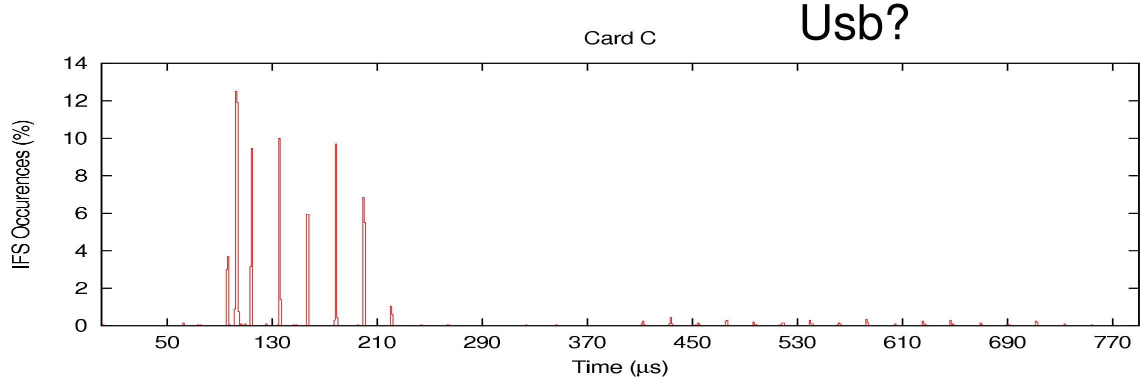


Backoff Analysis

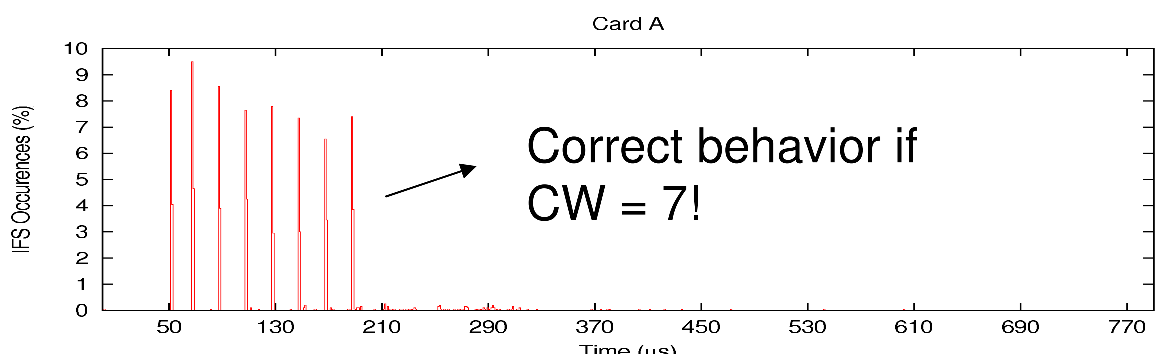
DWL122



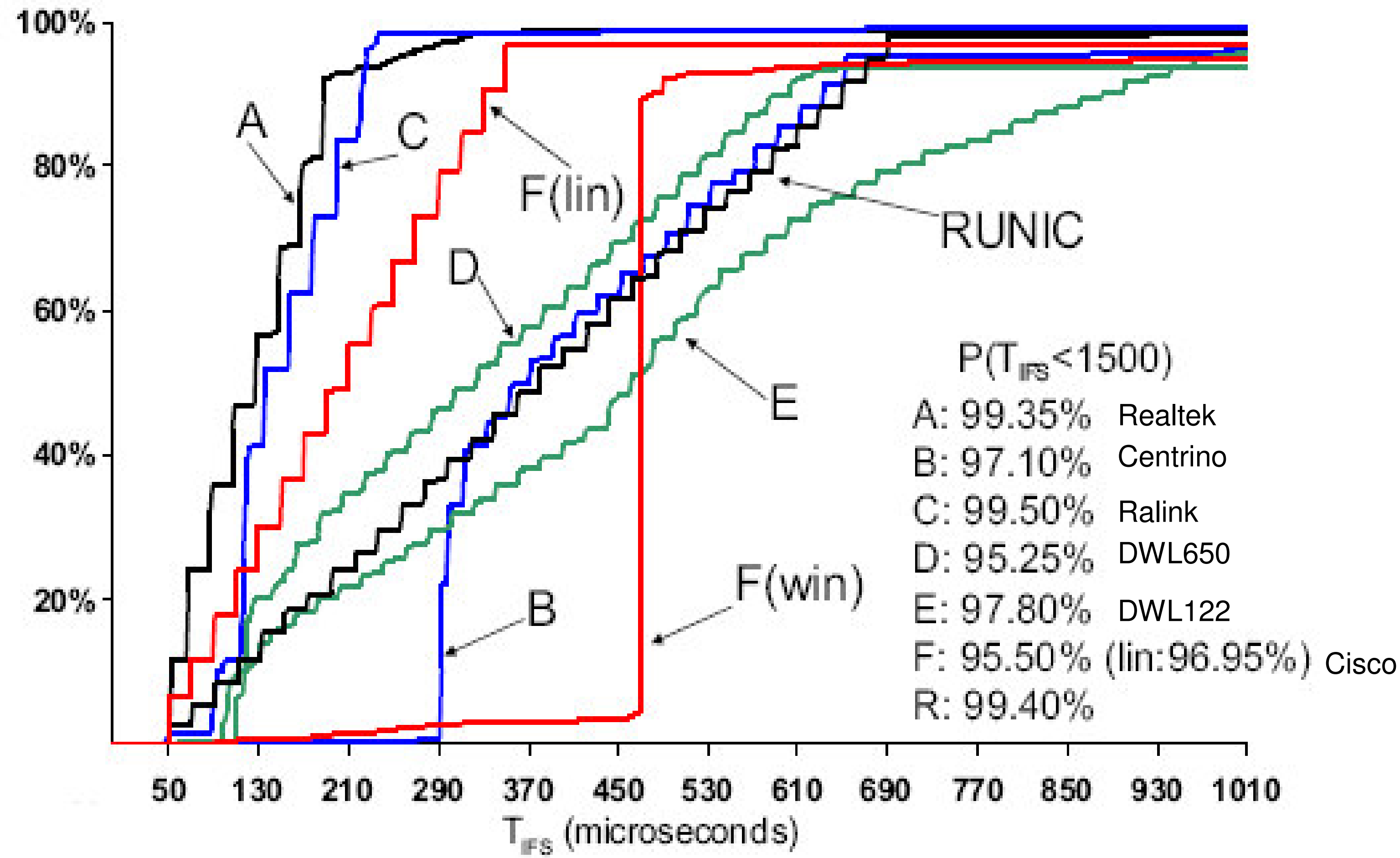
Ralink



Realtek



Backoff Analysis Summary



OS strongly affects the card F performance!

Relaxed Backoff Analysis

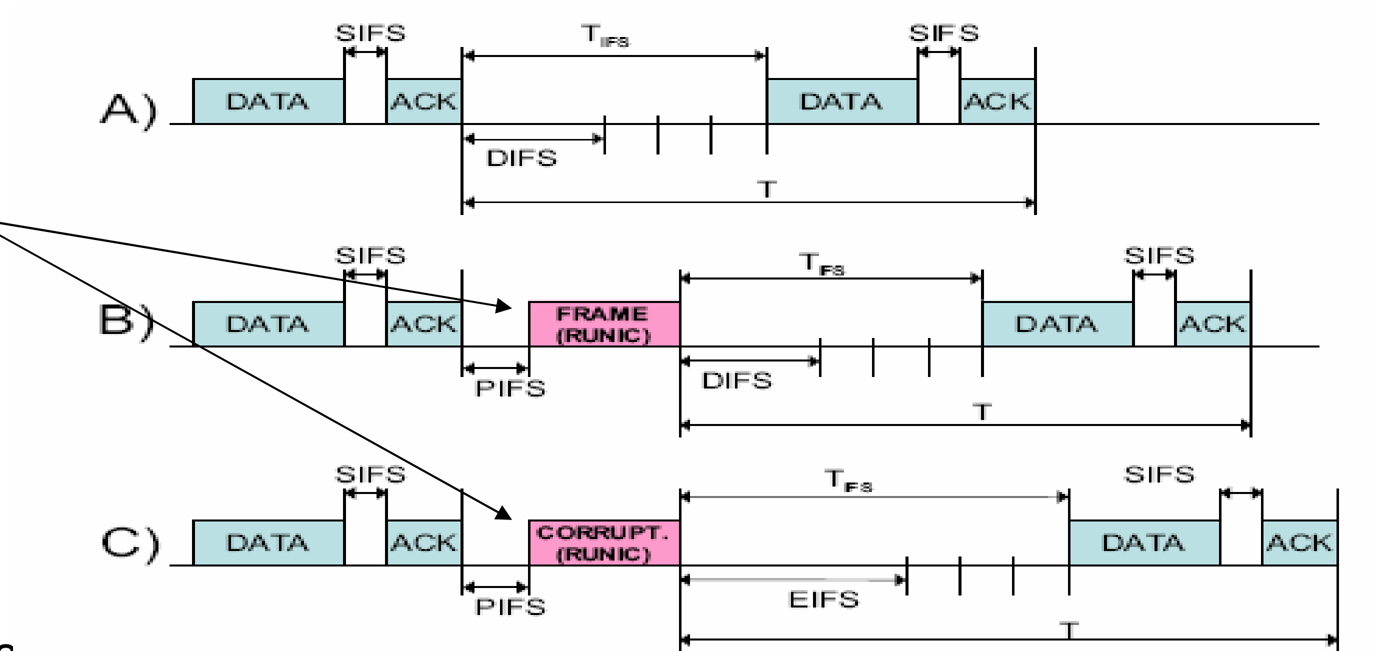
A) *HOL Processing delay*

By delaying artificially the backoff starting of new packets

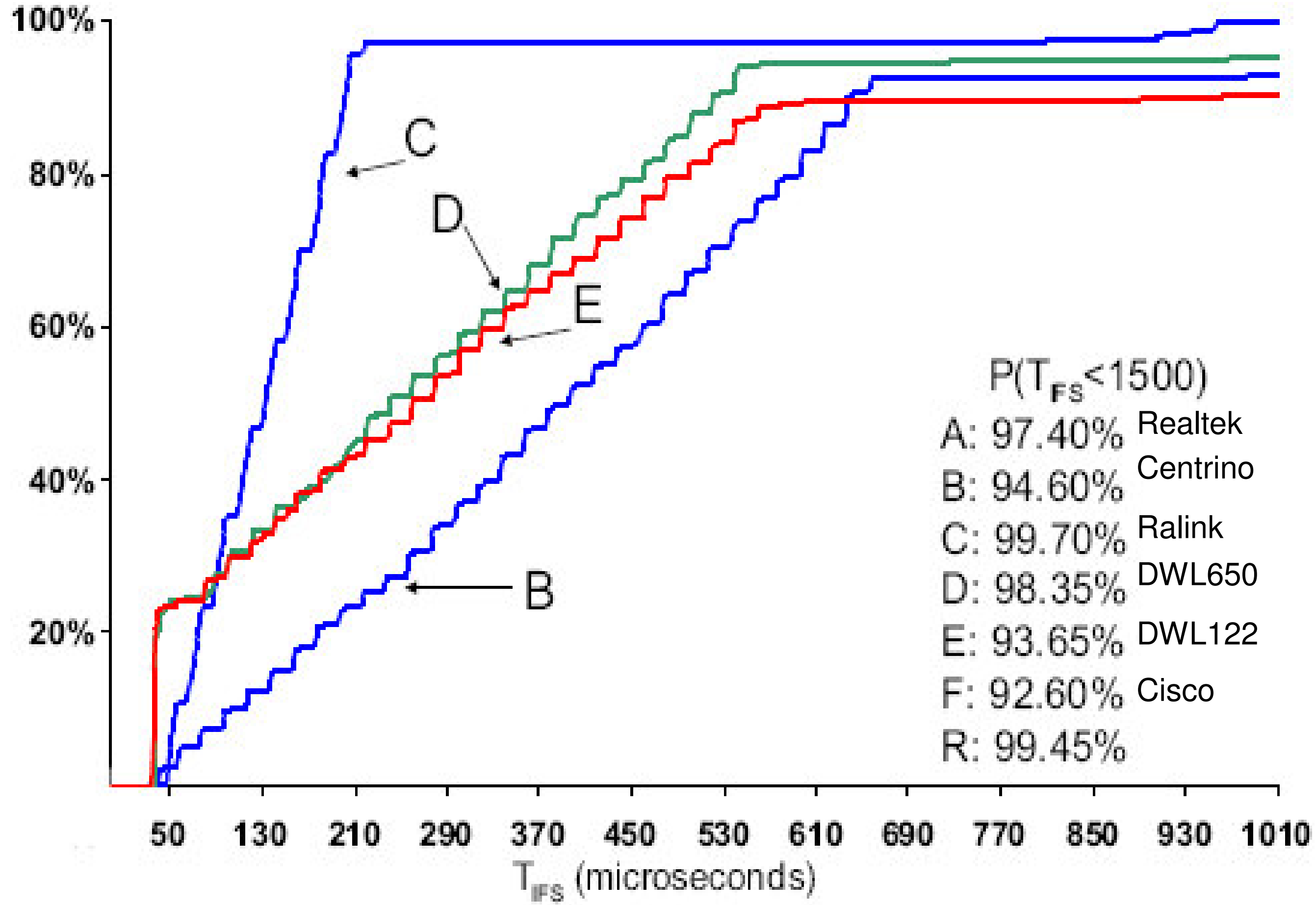
B) EIFS Implementation

By observing inter-frame times which follow the reception of a corrupted frame

Our card as a synchronized channel perturbator



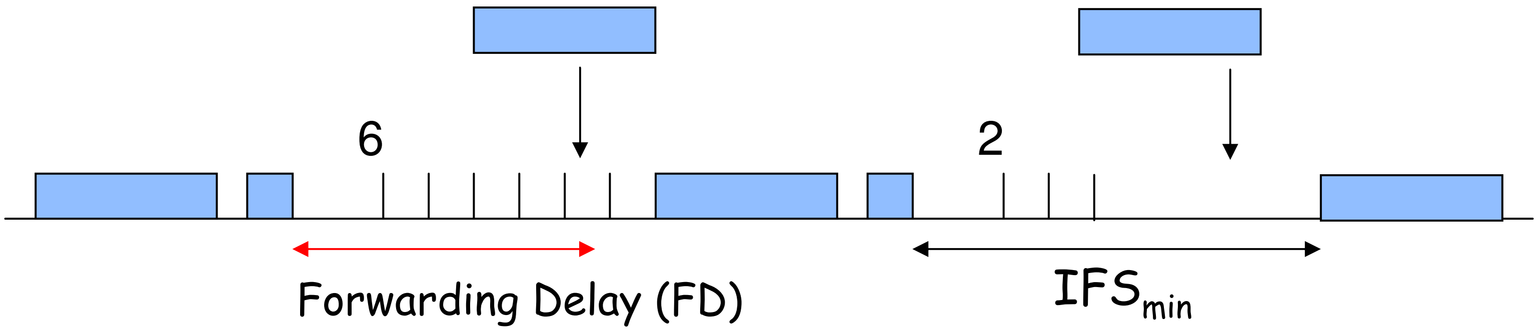
Relaxed Backoff Analysis



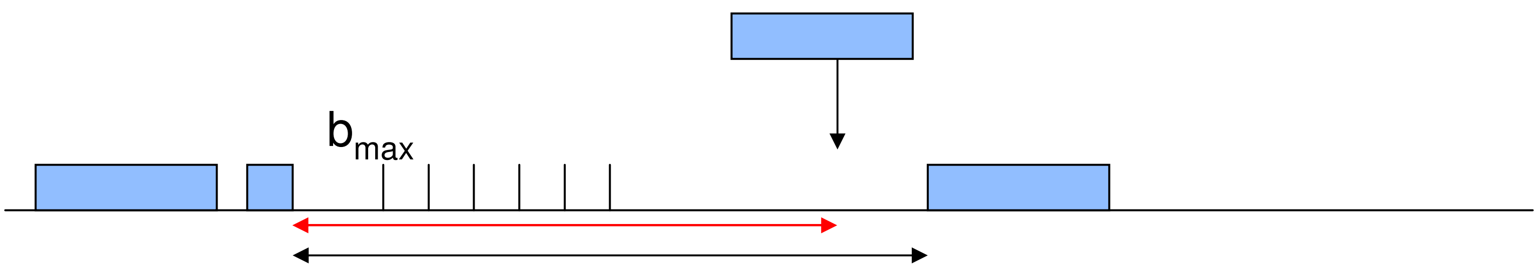
Why some misbehaviors disappear ?

Packet delays and post-backoff

Our hypothesis: whenever the data forwarding to the MAC is managed packet by packet, the stations do not really work in saturation: according to the post-backoff extraction some packets are immediately transmitted



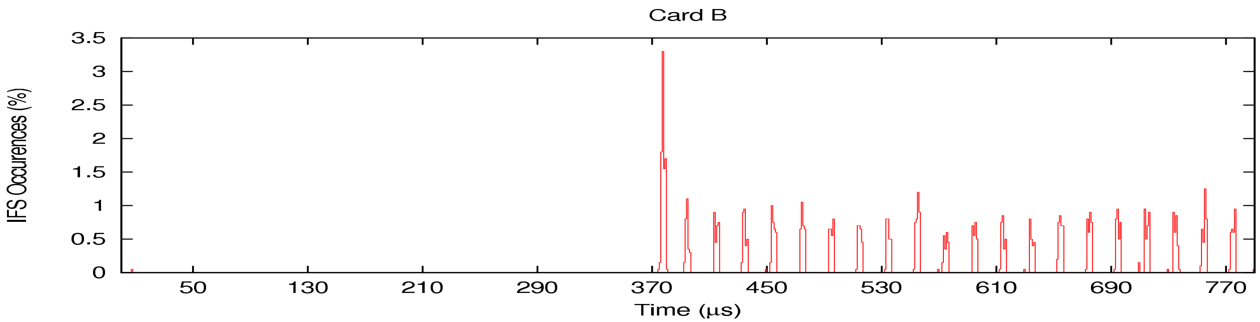
For b=0,1,2,3,4 the IFS is always IFS_{min}!



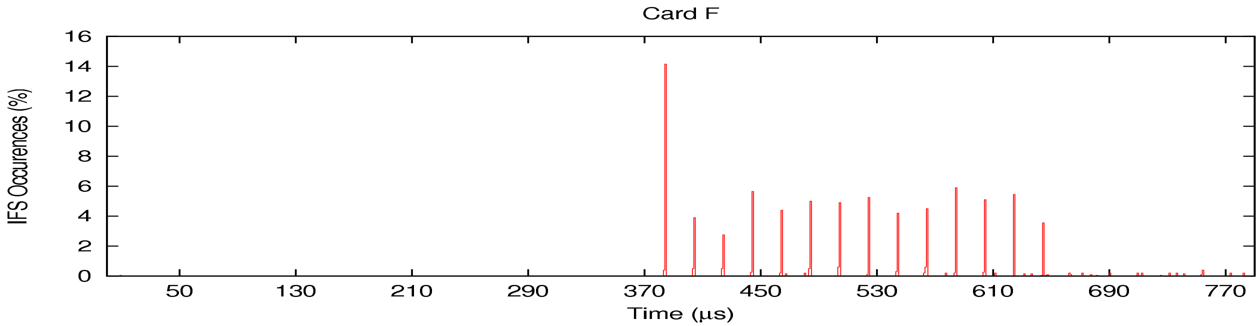
For FD > b_{max} , all the IFS are fixed to FD+DIFS

EIFS analysis

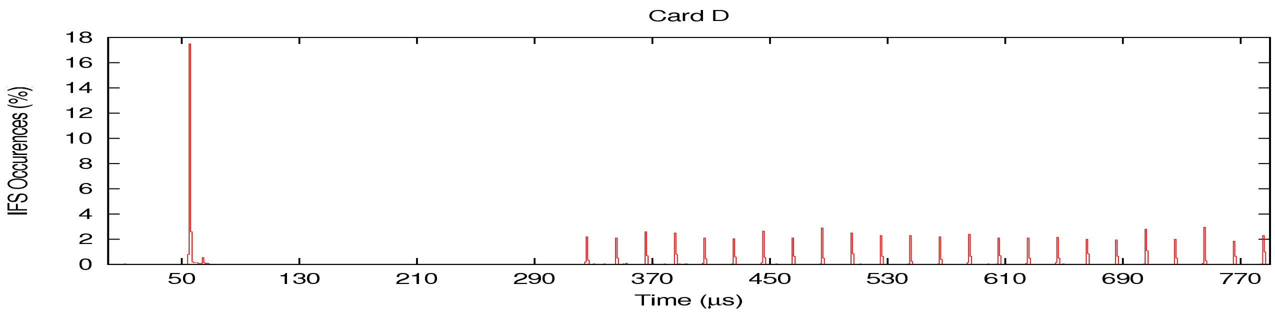
Centrino



Cisco



DWL650

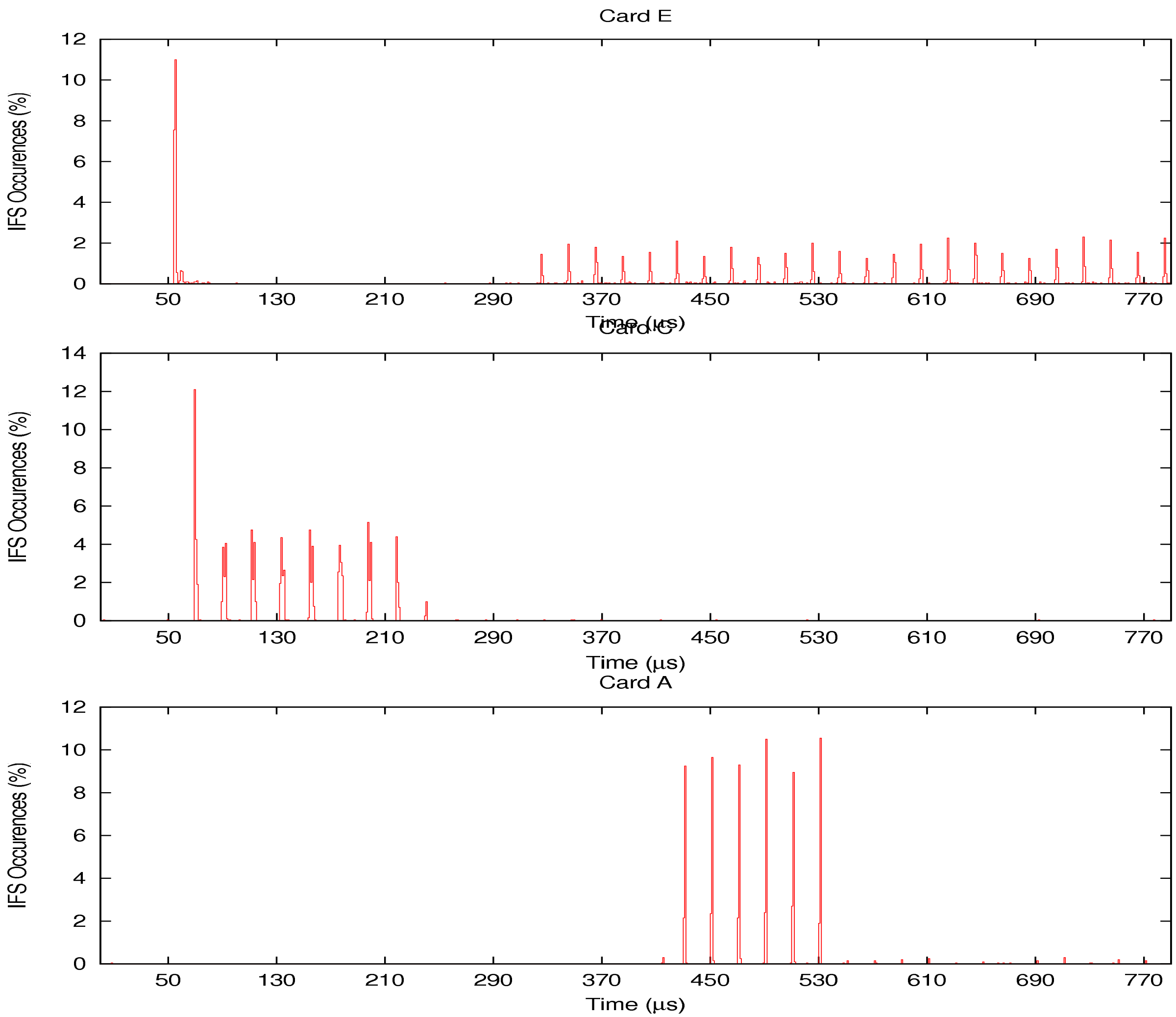


EIFS analysis

DWL122

Ralink

Realtek



Conclusions

- WiFi does not imply standard Fidelity

-Performance unfairness due to different hardware/firmware implementations rather than on measurement conditions

-In such a scenario:

  -how to provide QoS guarantee by means of EDCA??

  -how to define standard-compliancy tests?

Emerging networking scenarios

Birth of Mesh Networks (end of 90’)

- **Community-owned Wireless Networks (CWN)**
  - Seattle Wireless; San Francisco Wireless; NYC Wireless
  - … and tons of similar initiatives worldwide

- **CWN motto**
  - NYASPTWYOMB
    - Not Yet Another Service Provider To Whom You Owe Monthly Bill
  - from Seattle Wireless FAQ:
    - **The point of our CWN is to** create a local network infrastructure that replaces the local loop **that is, right now, owned by the telcos and other large corporations. [...]** The network isn't competing with the Internet, it is working in conjunction with the Internet to supplement ways for you to better use connectivity.

CWN deployment

- **802.11-based <u>very</u> cheap equipments**
  - ⇨ Antennas, APs, cards
  - ⇨ Often based on own-built antennas

- **802.11 for both client access and inter-AP connectivity**
- **Open-source routing solutions**
- **"How to set-up your own node" – instructions available!**

CWN bias in lessons learned: people involved <u>ARE</u> experts; Management burden (frequency planning, configuration, etc) completely unaccounted by CWN-ers (management and trouble-shooting = …a lot of fun…)

CWN nearer than we think

http://www.ninux.org
http://unituscolo2.servebeer.com

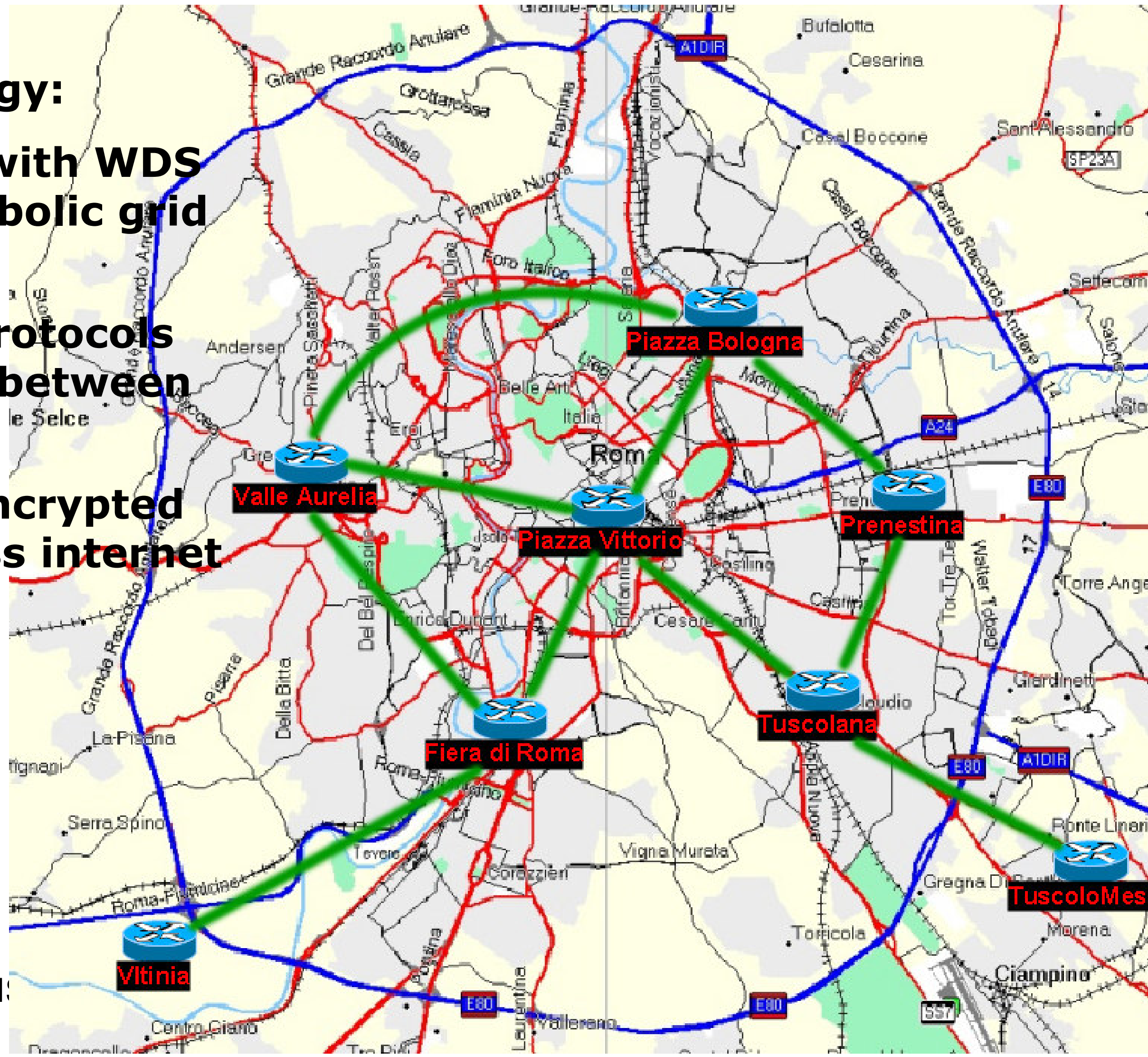
Wireless Community of Rome

Network Topology:

APs connected with WDS links using parabolic grid antennas

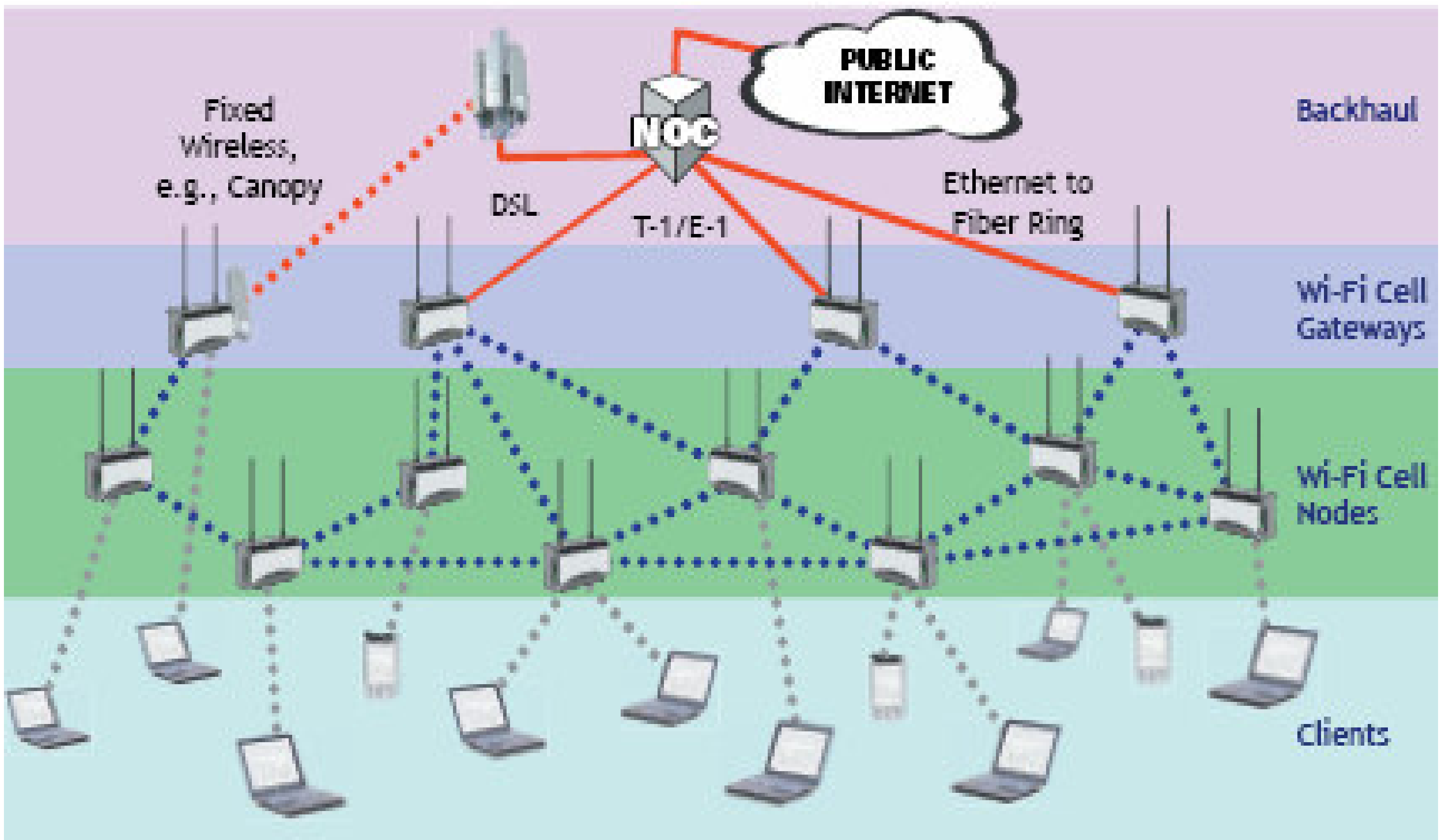
RIP and OSPF protocols exchage routes between APs

Point to point encrypted tunnels to access internet securely



Proprietary mesh: Extended access network

Source: Tropos Networks



Hierarchical structure; wireless backhaul not necessarily 802.11 (e.g. 802.16)

Standardization: 802.11s

- **Mesh have been <u>officially</u> recognized as a possible/likely 802.11 extension**

- **802.11s PAR (Proposed Authorization Request)**
  - Draft PAR: September 17, 2003
  - PAR applications: June 24, 2004
  - Draft Amendment to STANDARD [FOR] Information Technology-Telecommunications and information exchange between systems-Local and Metropolitan networks-Specific requirements-Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: <u>IEEE 802.11 ESS Mesh</u>.

802.11s entering into play

- **QUOTING FROM 802.11S PAR:**
- **802.11s scope:**
  - **To develop an IEEE 802.11 Extended Service Set (ESS) Mesh* with an IEEE 802.11 Wireless Distribution System (WDS)** using the IEEE 802.11 MAC/PHY layers **that supports both broadcast/multicast and unicast delivery over** self-configuring multi-hop topologies**.**
- **802.11s Purpose:**
  - **The IEEE 802.11-1999 (2003 edition) standard provides a four-address frame format for exchanging data packets between APs for the purpose of creating a Wireless Distribution System (WDS), but does not define how to configure or use a WDS. The purpose of the project is to** provide a protocol for auto-configuring paths between APs over self-configuring multi-hop topologies in a WDS **to support both broadcast/multicast and unicast traffic in an ESS Mesh** using the four-address frame format or an extension**.**