



# Analysis and Evaluation of WiFi Scanning Strategies



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# Handover Process

- **Set of mechanisms that manages cell transition of a MS between different APs**
  - Minimize *Disconnection Time* between MS and AP
  - Avoid undesired effects on the upper layers
  
- ***Horizontal Handover***
  - Cell transition occurs between points of attachment implementing the same link technology
  
- ***Vertical Handover***
  - Cell transition implies a variation on the link technology, for instance, a MS leaving a 802.11 coverage area where only a 3G cellular link is available
  
- ***Layer 2 Handover***
  - AP transition
  
- ***Layer 3 Handover***
  - AP transition also implies modifications in the Network Layer



# Handover Process

## ■ *Handover Phases*

### ■ **Scanning**

- *The MS searches candidate APs*

- *Passive Scanning*

- *Active Scanning*

### ■ **Authentication**

- *Selected AP validates MS identity*

### ■ **Association**

- *MS is registered with an AP to gain access to the network*



## Handover Process

### ■ ***The Handover Latency***

#### ■ **Scanning Latency dependencies:**

- Channels are **probed for activity** during *MinChannelTime* and *MaxChannelTime*
- **MS** must wait for AP's responses
- Timers setting **defines** the Scanning Latency

- **Authentication and Association delays** are related to transmission delays of Management Frames

**Scanning implies the 90%  
of the Handover Latency**



# Scanning Strategies

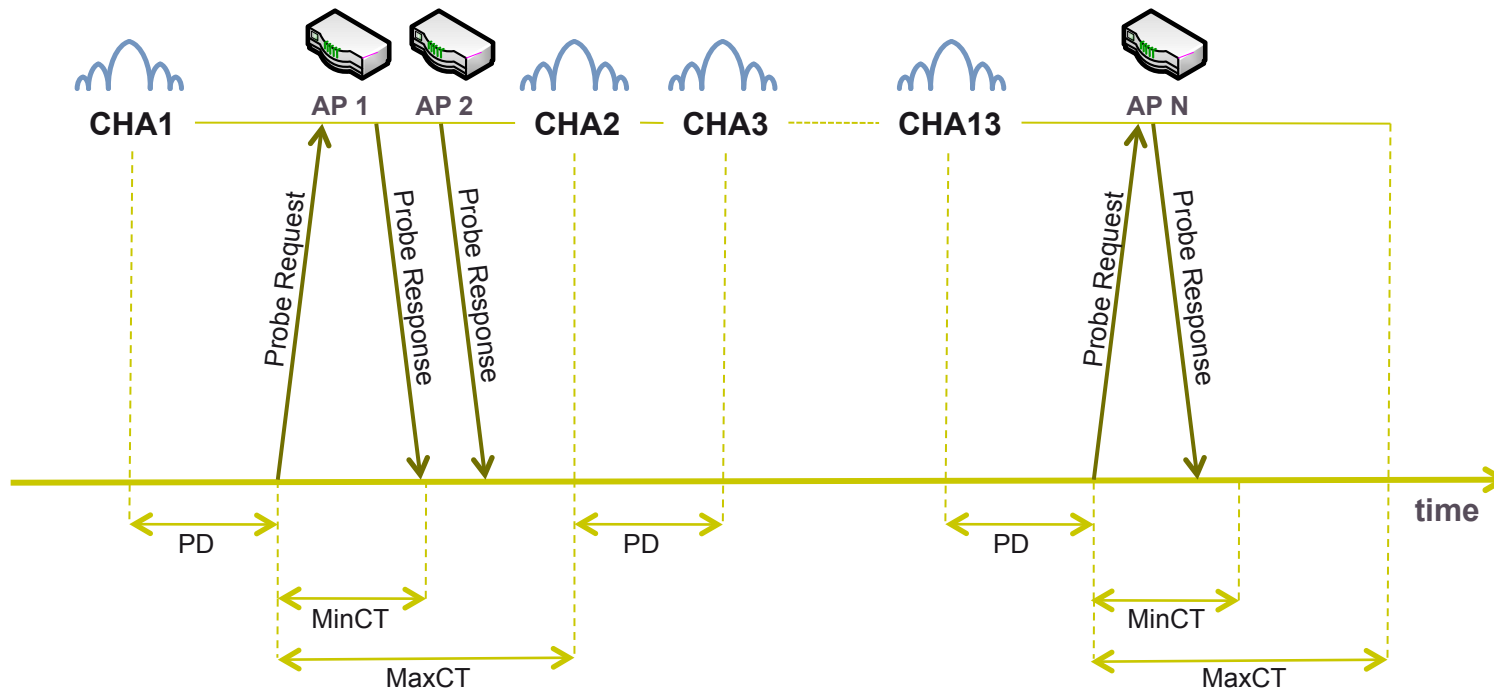
## ■ **IEEE Std 802.11 2007**

### • **Active Scanning**

1. Set on the first channel and wait for Probe Delay or a PHYRxStart indication.
2. Perform the basic channel access: wait DIFS + backoff
3. Send a broadcast *Probe Request*
4. Wait for **MinChannelTime**
5. If a *Probe Response* was received, then switch the timer to **MaxChannelTime** and process all received *Probe Responses*
6. If *no Probe Response* is received switch to the next channel after **MinChannelTime** expires

# Scanning Strategies

## Active Scanning





## Scanning Timers

- ***MinChannelTime***

- The minimum time to wait on each channel while scanning
- *The maximum time for an AP to answer a Probe Request*

**RISK** →

If the Probe Response's delay is greater than *MinChannelTime*, a channel is erroneously declared empty → Greater scanning **failure**

- ***MaxChannelTime***

- The maximum time to wait on a channel while scanning
- *The maximum time to collect responses from all APs on each channel.*

**RISK** →

High values for *MaxChannelTime* could be wasted time → Greater scanning **latency**





## Fixed Timers Scanning

- ***MinChannelTime*** and ***MaxChannelTime*** are statically set in the MS driver
- **Open problem:**  
The standard ***does not*** provide concrete values for both timers. Just a restriction:

$$\mathbf{MaxChannelTime \geq MinChannelTime}$$



## Fixed Timers Scanning

- **State of The Art**

Velayos et al:

**MinChannelTime = 1ms**

**MaxChannelTime = 10ms**

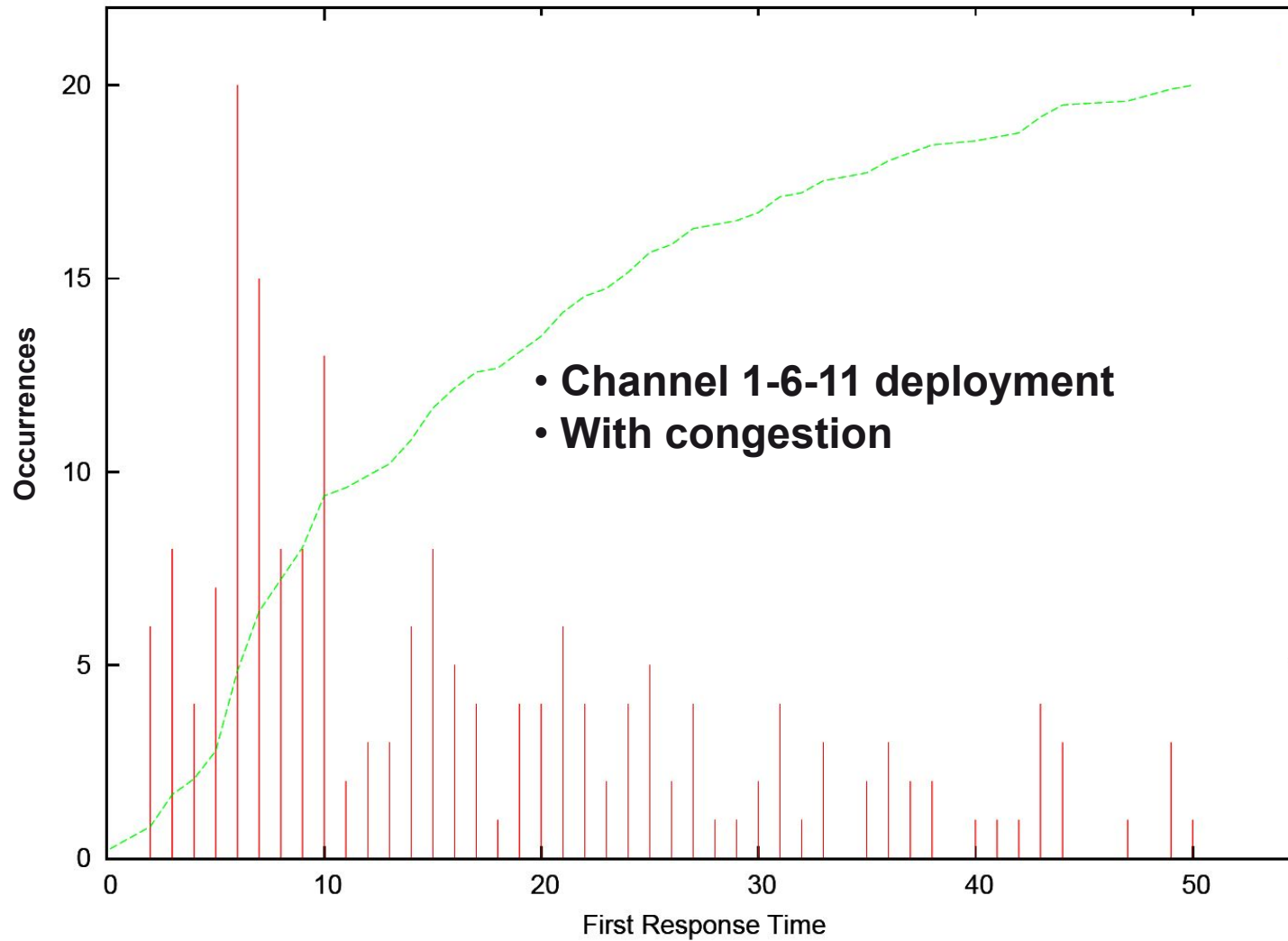
For the case of **MinChannelTime** comes from the minimal sending time:

$$DIFS + (aCW \text{ min} \times aSlotTime)$$

**Can we really consider these values for the scanning in practice?**



# Probe response's delay distribution: non overlapping channels.



# Adaptive Scanning

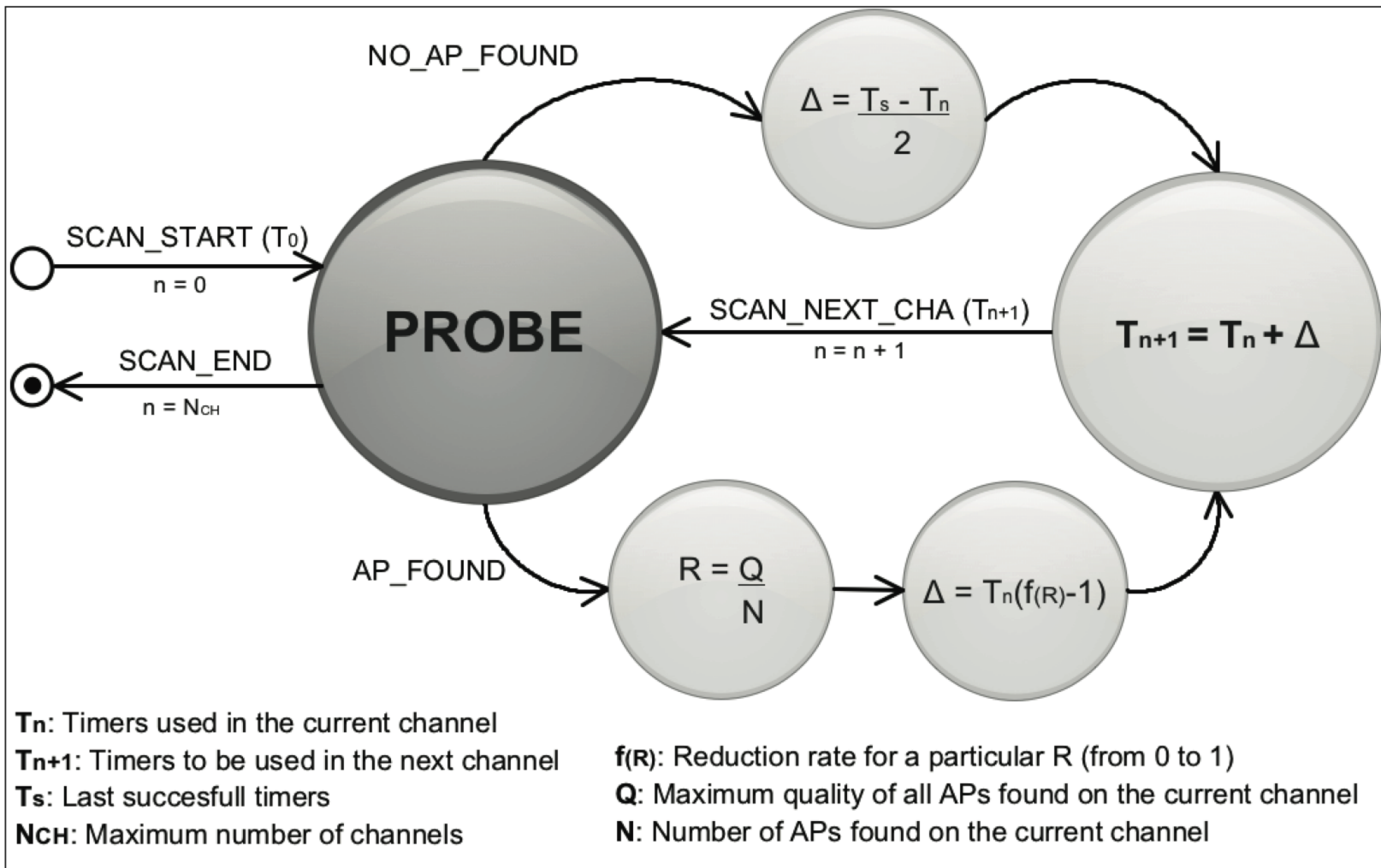
- **Our Goal:** Dynamic adjustment of timers during the scanning to avoid failure and keep a reduced latency
- Processing of probe responses on each channel to calculate next timers to apply for the next channel
- **Parameters to decide how to reduce the timers:**
  - Signal quality of the replier AP (Q)
  - Number of APs per channel (N)
  - Traffic load
- **Timers' bounds are adapted**
  - Defined by experimentation
- **How channels are switched?**
  - Two random subsequences to prioritize non-overlapping channels

1	6	11	2	3	4	5	7	8	9	10	12	13
1st s subsequence			2nd s subsequence									

11	1	6	12	8	10	5	2	3	13	9	4	7
1st s subsequence			2nd s subsequence									

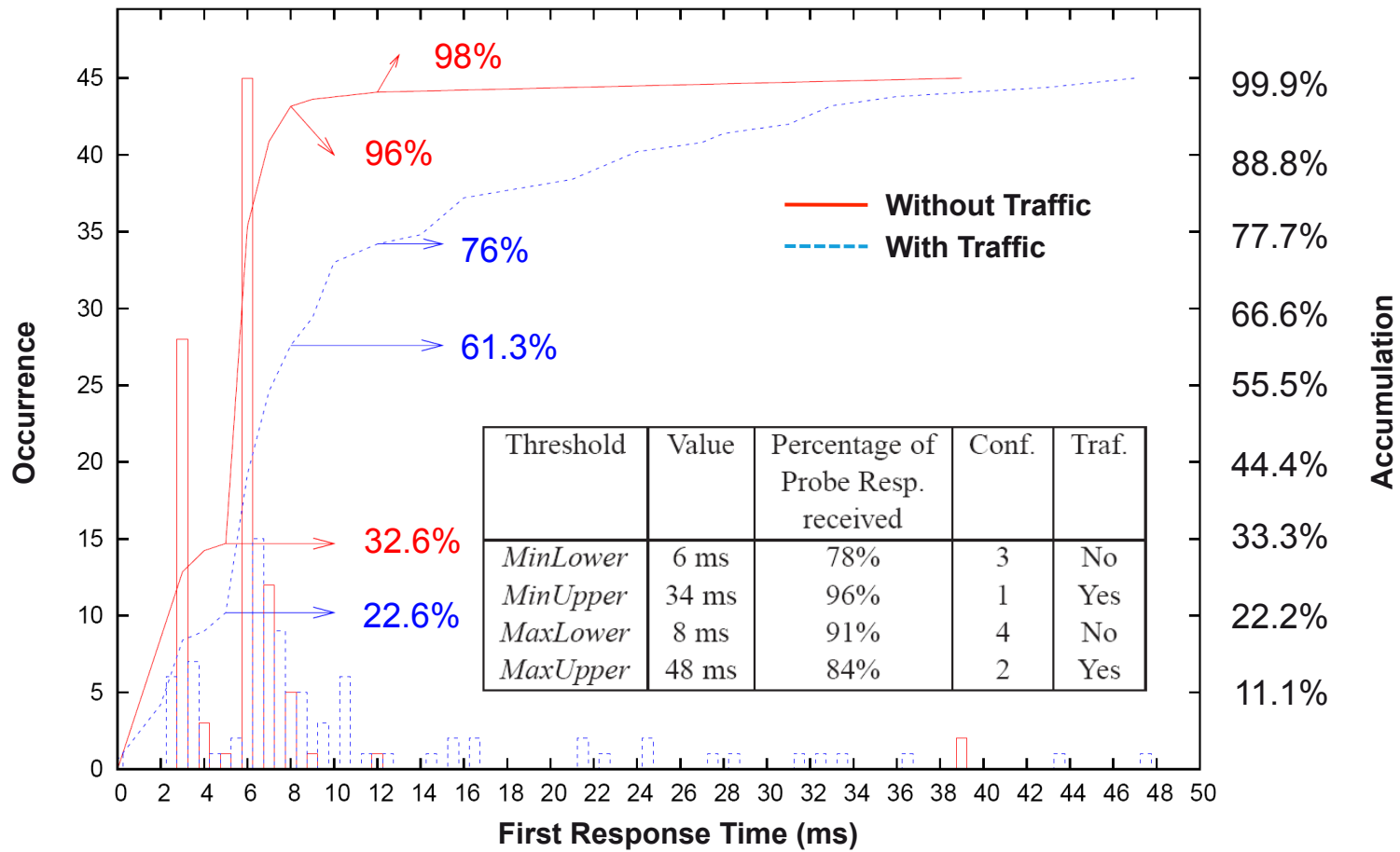
# Adaptive Scanning





# Adaptive Scanning

- **Threshold Definition of *MinChannelTime* and *MaxChannelTime***
  - **First and Further Responses Histograms**





## Failure vs. Latency trade-off

- We have implemented an **ad-hoc simulator** to study a wide range of cases
- The probe response's delay (in abscise) **varied using a uniform distribution**
- Latency (left ordinate) and failure (right ordinate) values have been analyzed for both **Fixed Timers** (<10,20> ms and <25,50> ms) and **Adaptive** scanning.
- Different scanning sequences have been evaluated
  - Sequential scanning bias the behavior in worst sequences

Optimistic Sequences  
BEST SEQUENCES

1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0
.....												
1	1	1	1	1	1	1	1	1	1	1	1	0

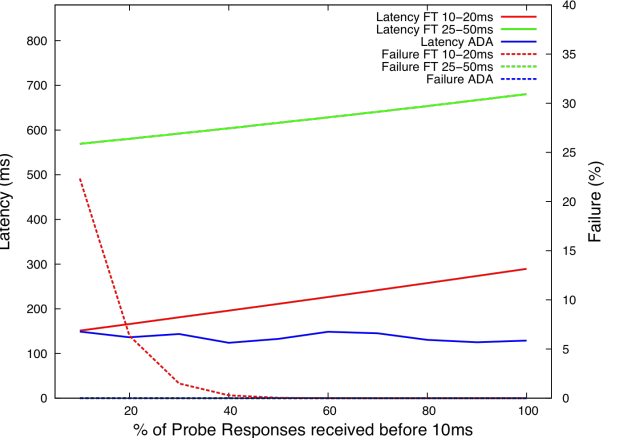
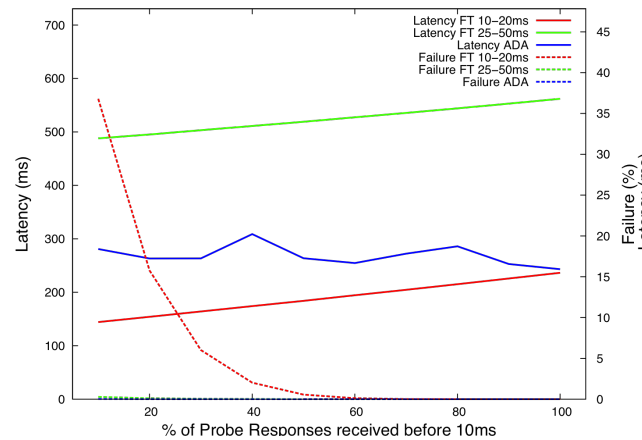
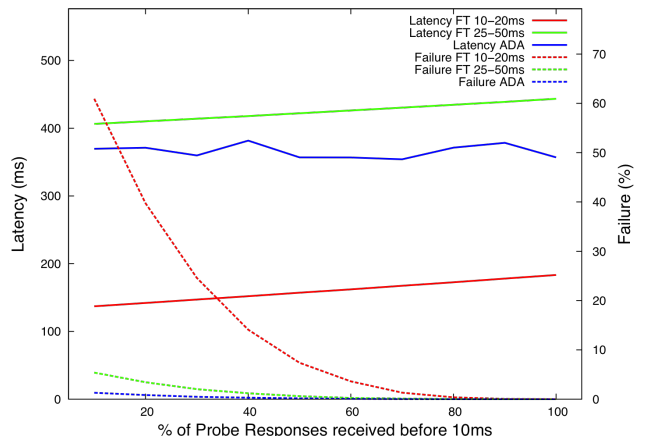
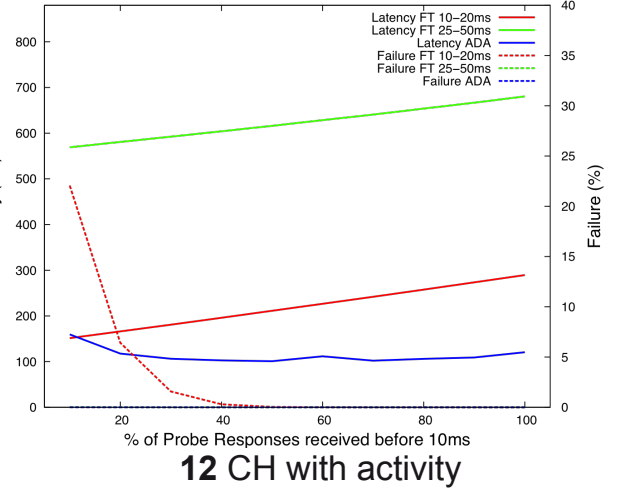
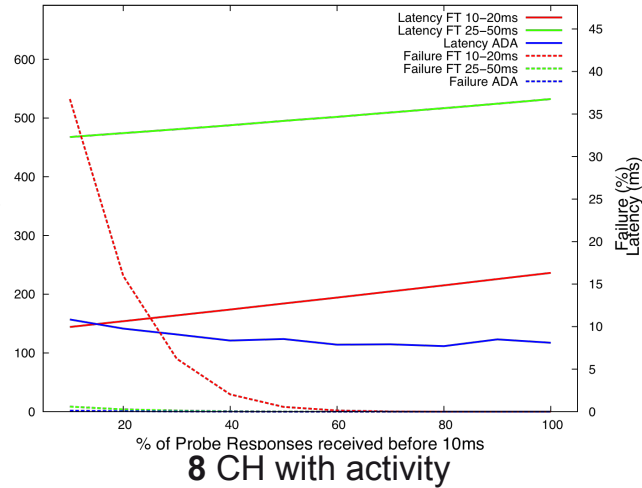
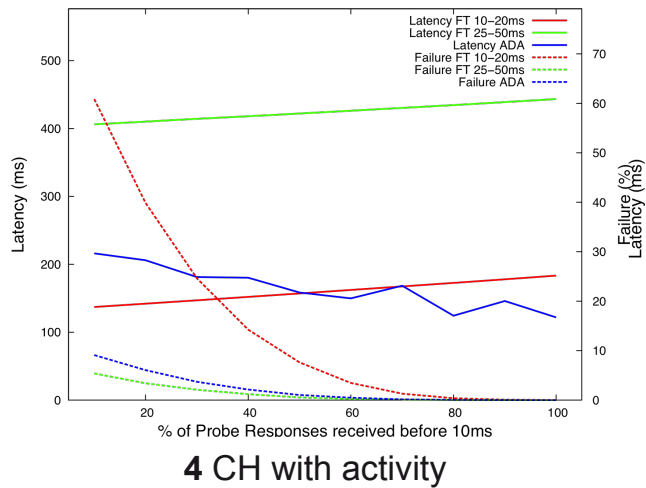
Pessimistic Sequences  
WORST SEQUENCES

0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	1	1
.....													
0	1	1	1	1	1	1	1	1	1	1	1	1	1

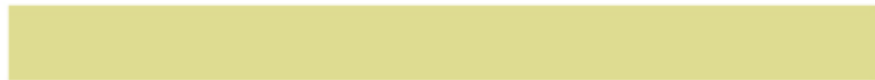


# Full Scanning Failure vs. Full Scanning Latency trade-off

## Optimistic Scenarios



## Pessimistic Scenarios



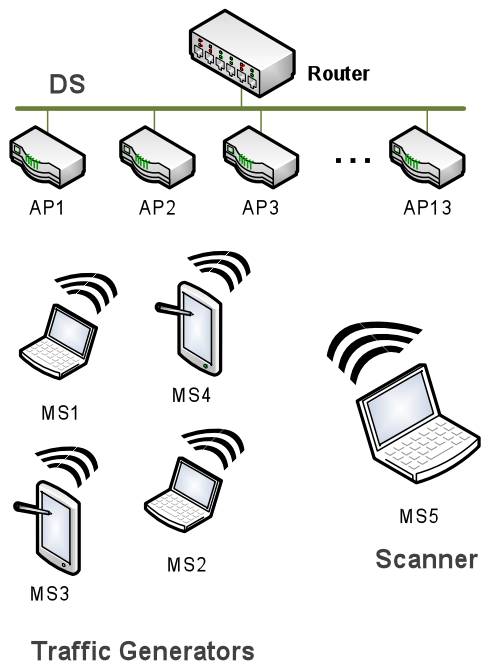




## Ongoing Experimentation Work

### ■ Modification of the *MadWiFi* Scanning Algorithm

- Implementation of the Fixed Timers scanning
- Implementation of the Adaptive scanning



#### ■ Configuration 1:

13 APs allocated one by one on channels 1 to 13  
(one AP per channel)

#### ■ Configuration 2:

13 APs all allocated on channel 11

#### ■ Configuration 3:

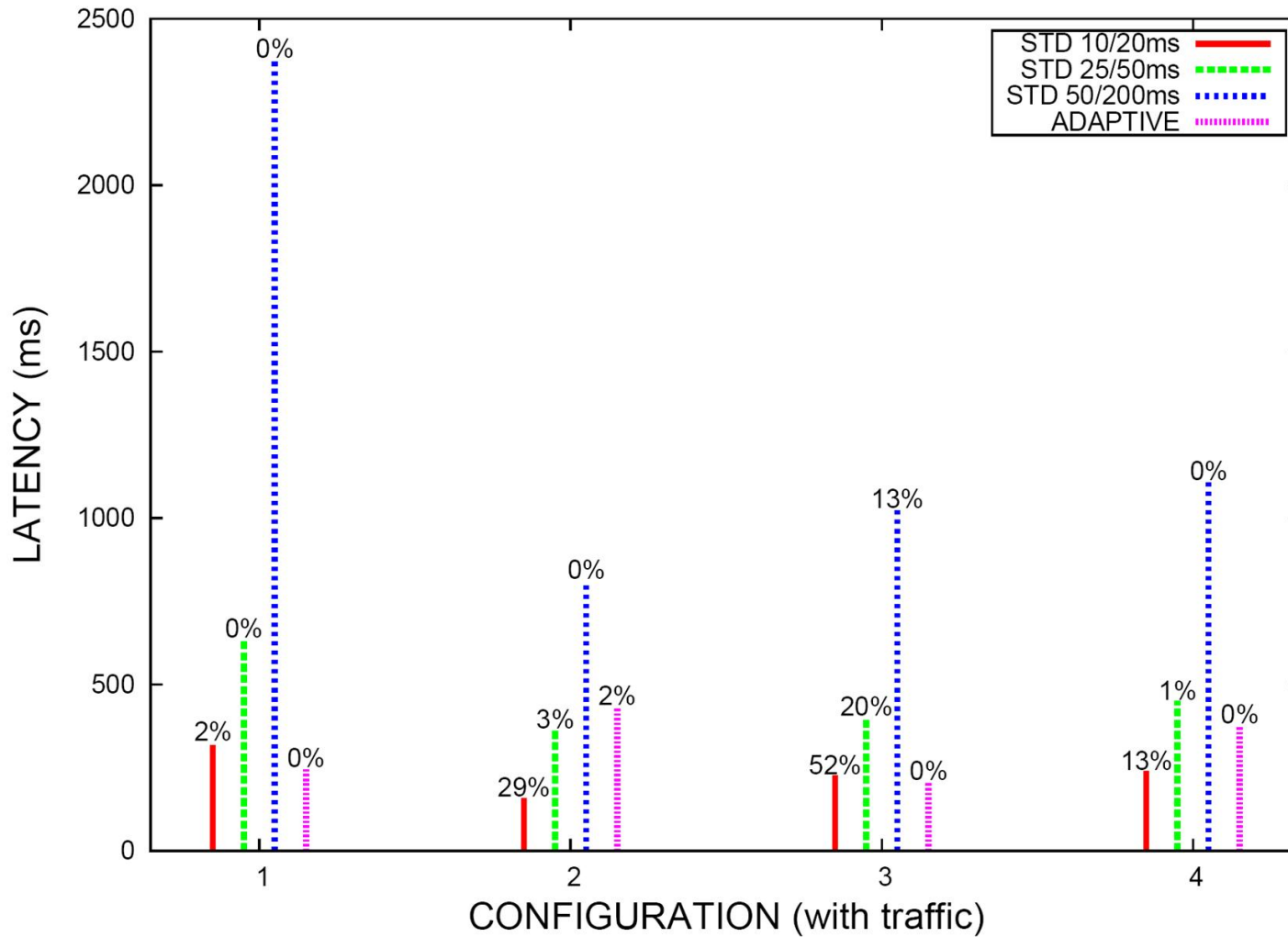
3 APs allocated one by one on channels 1,6 and 11  
(one AP per channel)

#### ■ Configuration 4:

12 APs allocated by four on channels 1,6 and 11  
(four AP per channel)



## Ongoing Experimentation Work



Promising  
Results:  
Lowest failure  
Lowest latency



## Conclusions

- The delay of probe responses in a congested environment, **impacts severely** 802.11 Scanning with fixed timers
- We have **improved the scanning time** by adapting scanning timers based on dynamically collected information
- Scanning adaptation function can be improved
  - For pessimistic scenarios adaptation is slow



## Future Work

- **Focus on the analysis of a proper adaptation function.**
  - *Adapting both MinCT and MaxCT independently, e.g., based on current load.*
- **The AP Selection Policy**
  - *Which are the parameters for selecting the best AP from a set?*
- **Predictive Adaptation**
  - *Analysis of the Physical Signal to predict timer's settings.*
- **New Physical and MAC Layer Optimizations.**
  - *Force Probe Responses to arrive sooner using prioritized access to the channel (SIFS, PIFS or EDCA)*



**Thank you.  
Questions?**

