

Fairness issues
in a chain of
IEEE 802.11
emitters

B. Ducourthial
Y. Khaled,
S. Mottelet

802.11 issues

Chain of
stations

Simulations

Modeling

Analysis

Perspectives

Fairness issues in a chain of IEEE 802.11 emitters

B. Ducourthial, Y. Khaled, S. Mottelet

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- 1 IEEE 802.11 research issues
- 2 Case study : 3 pairs scenario
- 3 Simulations with many pairs
- 4 Modeling
- 5 Analysis
- 6 Perspectives for the fairness improvement



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Wireless network issues

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4. transport

3. network

2. link

1. physical

- Layers design
International Organization for Standardization (ISO)
Open Systems Interconnection (OSI)
Basic Reference Model (ISO/IEC 7498-1 : 1994)

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4					
.....					
3					
.....					
2	<table border="1"> <tr> <td>LLC</td> <td>IEEE 802.2 Logical Link Control</td> </tr> <tr> <td>MAC</td> <td>Medium Access Control</td> </tr> </table>	LLC	IEEE 802.2 Logical Link Control	MAC	Medium Access Control
LLC	IEEE 802.2 Logical Link Control				
MAC	Medium Access Control				
.....					
1	PHY				
.....					

- Low layers specifications
LAN MAN Standards Committee
IEEE Std 802 Overview and Architecture



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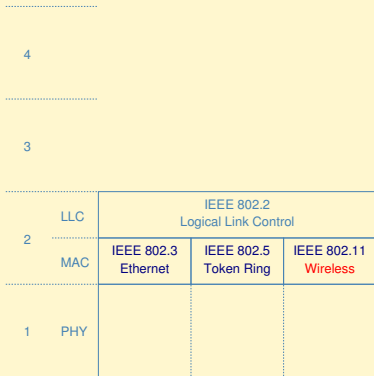
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- Several kind medium access techniques



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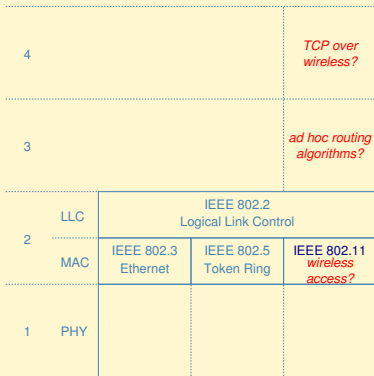
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- Wireless networks research issues
 - data flow transport cross layering... ~ BTP
 - routing OLSR, AODV... ~ HOP
 - medium access : performance, fairness...

Medium access techniques

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	LLC	IEEE 802.2 Logical Link Control		
2	MAC	IEEE 802.3 Ethernet	IEEE 802.5 Token Ring	IEEE 802.11 <i>wireless access?</i>
1	PHY			



Medium access techniques

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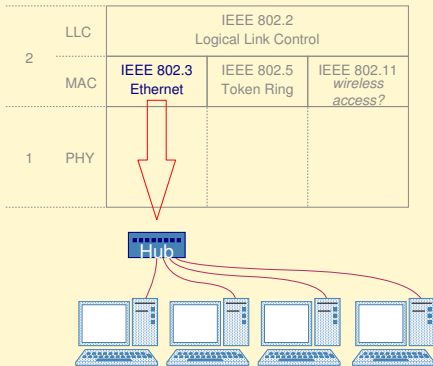
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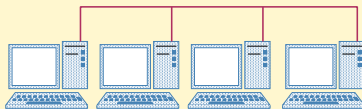
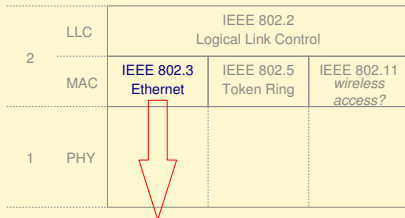
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- CSMA/CD

Carrier Sense Multiple Access / Collision Detection

- a station listens to the medium
- when it sends, it listens to what it sends
- in case of collision, it waits for a random delay



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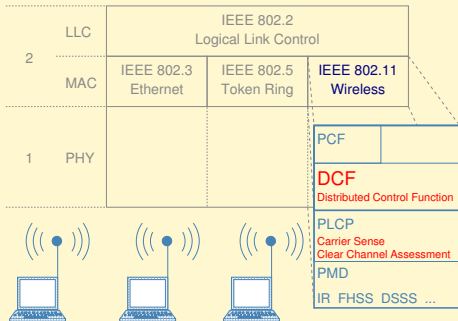
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- CSMA/CA

Carrier Sense Multiple Access / Collision **Avoidance**

- a station listens to the medium
- waits for a fixed delay before sending
Inter Frame Space, depends on the context
- waits for a random delay if the medium is not idle
decreases when the medium is idle during *aSlotTime*



Fairness issues in the IEEE 802.11 MAC

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- IEEE 802.11 characteristics
 - collision detection
 - a station cannot detect a collision by listening what it is sending
 - locality phenomena
 - a station may not hear all the other stations
- Consequences
 - preventive waiting (before sending)
 - in the DCF procedure of the MAC layer
 - spatial unfairness
- Bibliography
 - fairness defect descriptions
 - performance studies
 - new MAC layer propositions

[cf. references in the technical report]

http://www.hds.utc.fr/~ducourth/bib/rap_pairs.pdf



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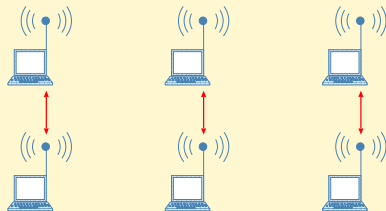
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3 pairs scenario



- spatial unfairness scenario
- highlighted by the use of extended IFS
[Dhoutaut Guérin-Lassous 2002]
- modeled and studied with Markov chains
[Chaudet Guérin-Lassous 2004]



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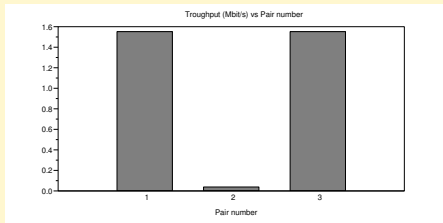
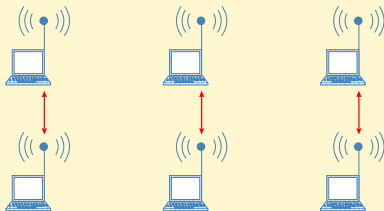
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3 pairs scenario

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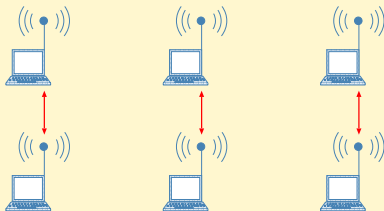
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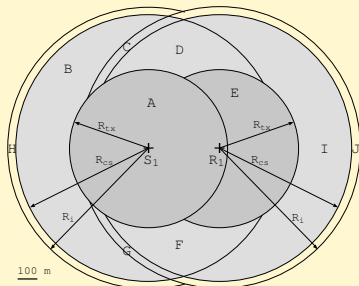
- our contribution

- context extension (delays)
- generalization to more than 3 pairs
- non Markovian modeling
- analytical study
- applications to fairness improvements

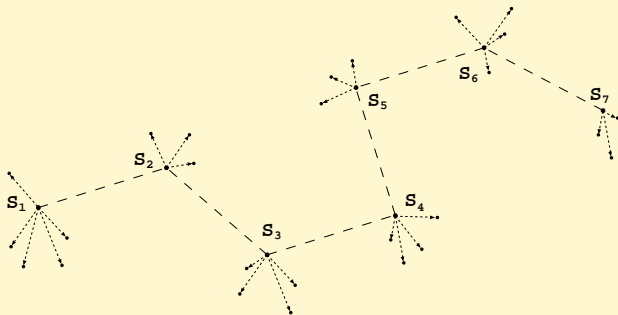


- Extended IFS not required

Example : Lucent Orinoco 802.11b device in outdoor environment with a 2 Mbits/s sending rate



- Extended IFS not required
- Chain of emitters



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Generalization to more than 3 pairs

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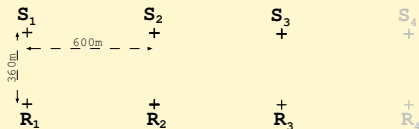
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- simulation with ns-2
- parameters of a Lucent Orinoco 802.11b device in outdoor environment :



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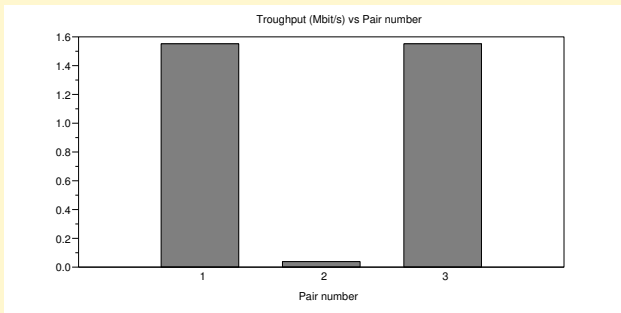
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- results :
 - influence of the parity of n (number of pairs)
 - asymptotic phenomena



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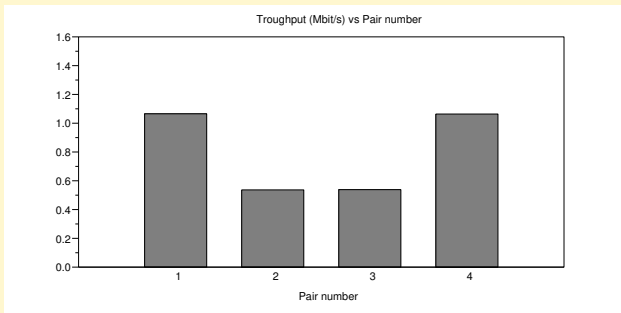
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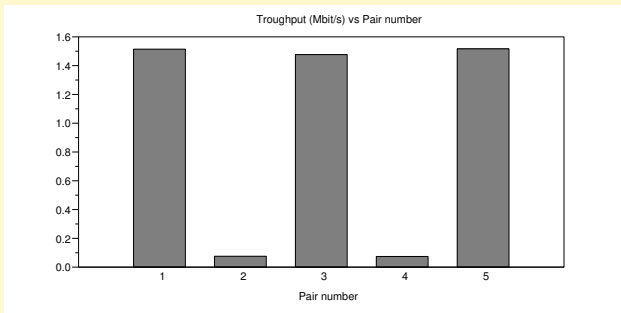
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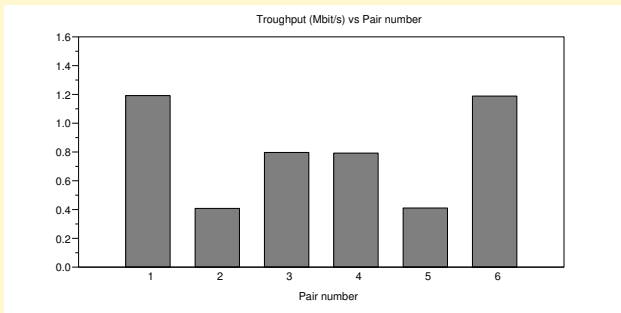
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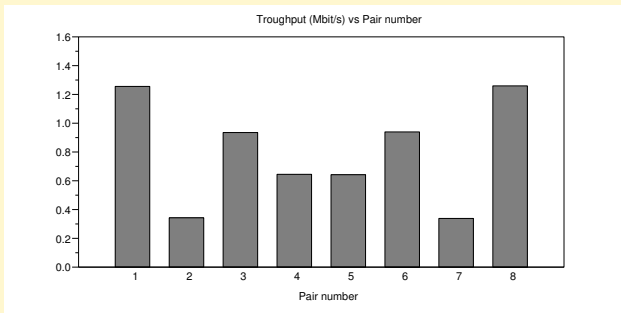
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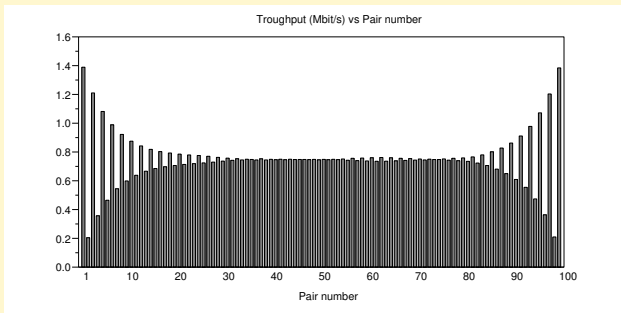
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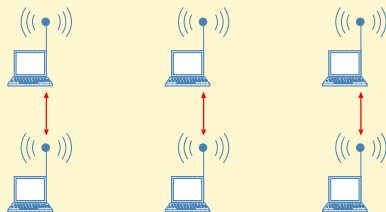
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Simple analytical model



- Simple model, scalable (non Markovian)

$$x_i = \alpha(1 - x_{i-1})(1 - x_{i+1}), \quad i = 1 \dots n$$

- Intuitive explanation

- listening before sending

↪ a pair can send only if its neighbors are idle

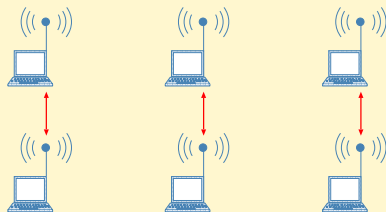
- preventive waiting

↪ a pair doesn't use all the idle time for sending

→ proportion α , with $0 < \alpha < 1$



Simple analytical model



- Simple model, scalable (non Markovian)

$$x_i = \alpha(1 - x_{i-1})(1 - x_{i+1}), \quad i = 1 \dots n$$

- Intuitive explanation

- Formal explanation

- y_i Bernouilli, 1 when the pair i is sending, 0 else
- z_i defined by $P(z_i = 1 | y_{i-1} = y_{i+1} = 0) = \alpha$
- $y_i = z_i (1 - y_{i-1}) (1 - y_{i+1})$
- $x_i = E[y_i] = \alpha P(y_{i-1} = y_{i+1} = 0)$



Modeling validation (1/2)

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- simulation ns-2 : $r_i(s, n)$
sending rate of a pair i in a chain of n stations
with a packet size s
- analytical model \rightsquigarrow scilab simulations : $x_i(\alpha, n)$
% of the time used for sending for a pair i in a chain of n
stations with a sending proportion α



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% of the time used for sending for a pair i in a chain of n
stations with a sending proportion α
- least squares root identification of the families

$$\left\{ \frac{r_i(s, n)}{r_1(s, n)} \quad 1 \leq i \leq n \right\} \quad \left\{ \frac{x_i(\alpha, n)}{x_1(\alpha, n)} \quad 1 \leq i \leq n \right\}$$



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- tests of T seconds, maximal sending rate r_{\max}
- the i^{th} pair sends during $t_i = x_i(\alpha, n) \times T$ sec
- it sends $r_i(s, n) \times T = r_{\max} \times t_i$ bytes
- thus $r_i(s, n)/t_i = r_{\max}/T = r_1(s, n)/t_1$
- thus $r_i(s, n)/r_1(s, n) = t_i/t_1 = x_i(\alpha, n)/x_1(\alpha, n)$



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\rightsquigarrow a value of α allows to find the ns-2 results
fitting proportion $\alpha^f(s, n)$ f for fit

\rightsquigarrow validates the model



Model validation (2/2)

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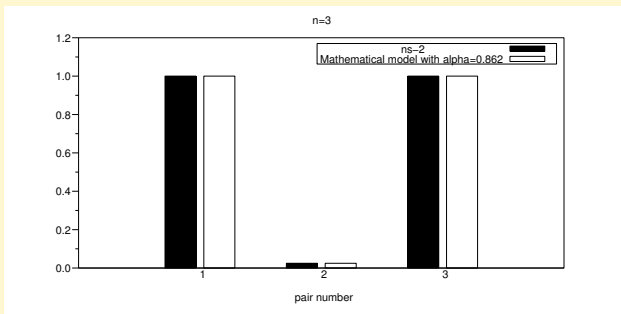
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- examples of fitting proportions
 - packets of 1500 bytes, 3 pairs :
 $\alpha^f(1500, 3) = 0.862$
 - packets of 1500 bytes, 7 pairs :
 $\alpha^f(1500, 7) = 0.812$



Model validation (2/2)

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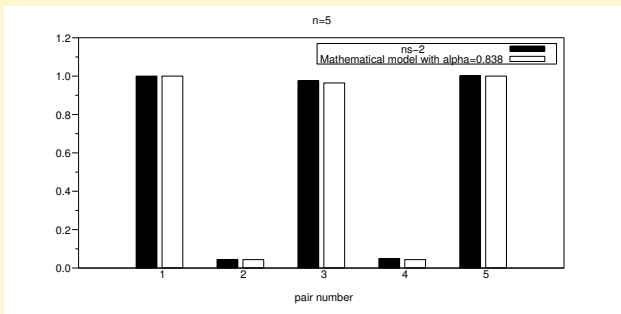
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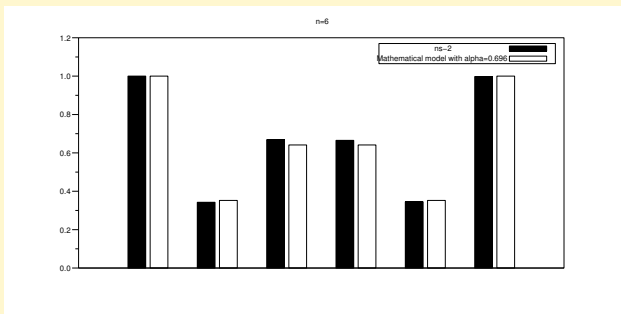
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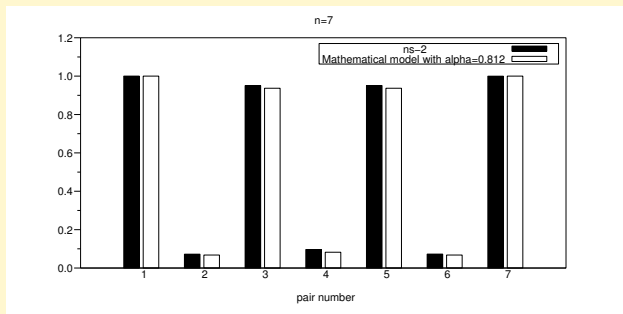
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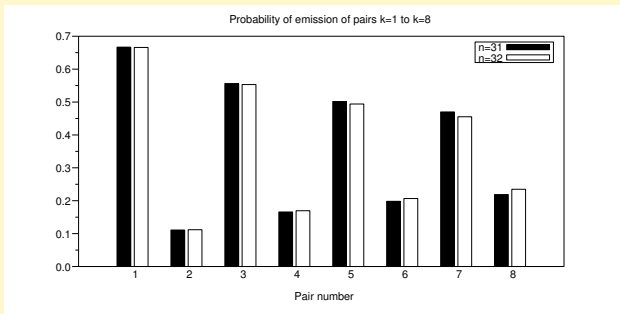
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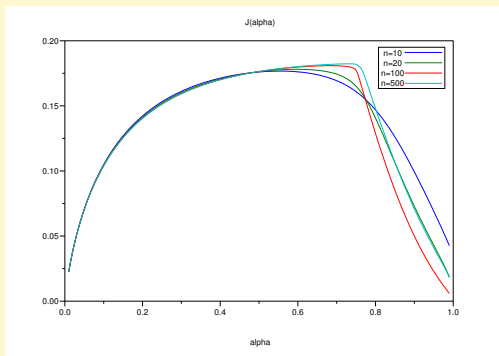
- Direct applications of the model
 - close formulae depending on α for the chains until 8 pairs
 - proof of a stable behavior existence for all the chains
 - asymptotic behavior similar to the one found with ns-2
- comparison of the sending probabilities for the pairs 1 to 8 for $n = 31$ and $n = 32$ with $\alpha = 0.75$:



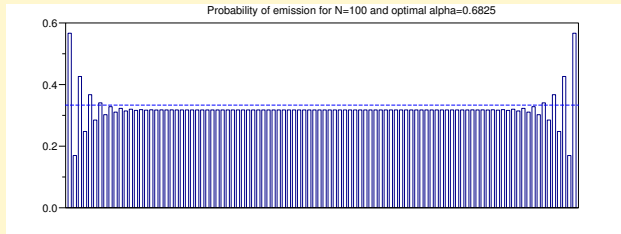
- Fairness versus proportion α
 - entropy $E(x) = -\sum_{k=1}^n x_k \log x_k$ [Jaynes57]
 - maximize

$$J(\alpha) = -1/n \sum_{i=1}^n x_i(\alpha, n) \log(x_i(\alpha, n))$$

↪ optimal proportion $\alpha^e(n)$ ^{e for entropy}

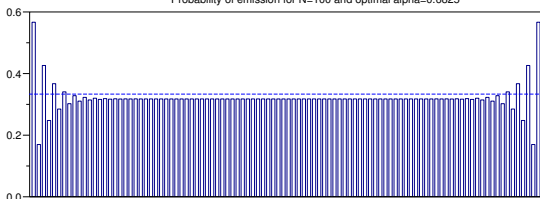


- Using the optimal proportion $\alpha^e(n)$ with scilab :
 - when n tends toward the infinity, $x_i(\alpha^e(n), n)$ shows a large center plate at $\frac{1}{3}$
example : sending probability for $n = 100$ and optimal proportion $\alpha^e(100)$:



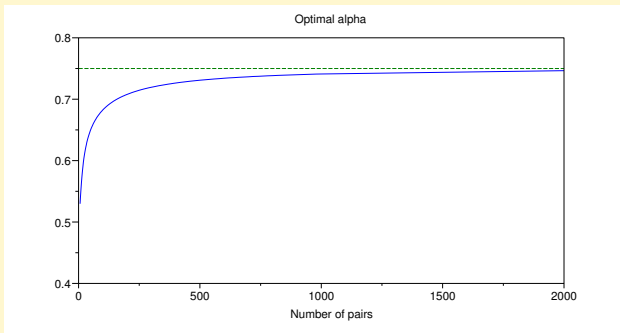
- Using the optimal proportion $\alpha^e(n)$ with scilab :
 - when n tends toward the infinity, $x_i(\alpha^e(n), n)$ shows a large center plate at $\frac{1}{3}$
example : sending probability for $n = 100$ and optimal proportion $\alpha^e(100)$:
 - this is the optimal probability in the center :
 - infinite chain (or large loop)
 - each pair i randomly draws u_i in $[a, b]$
 - the pair i reaches the channel if u_i is less than u_{i-1} and u_{i+1}
 - $P(u_i < u_{i+1}, u_i < u_{i-1}) = \frac{1}{3}$

Probability of emission for N=100 and optimal alpha=0.6825



- Behavior with the optimal proportion $\alpha^e(n)$:

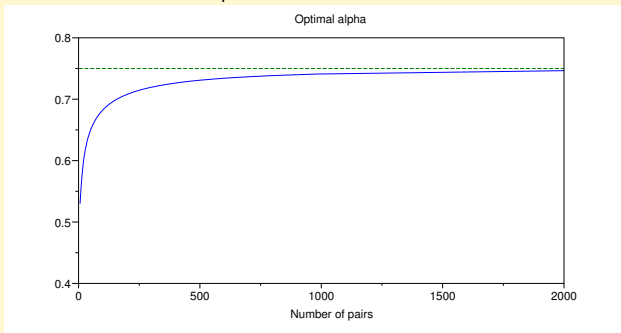
$$\alpha^e(n) \xrightarrow{n \rightarrow \infty} 3/4$$



- Behavior with the optimal proportion $\alpha^e(n)$:

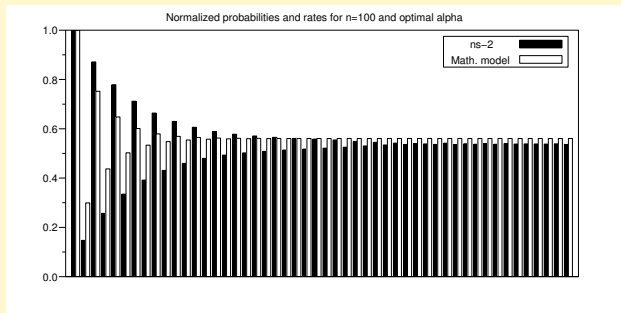
$$\alpha^e(n) \xrightarrow{n \rightarrow \infty} 3/4$$

- Asympt. proportion $3/4 \leftrightarrow$ optim. probability $\frac{1}{3}$
 - infinite chain (or large loop)
 - the equation system becomes $x_i = \alpha(1 - x_i)^2$
 - the entropy is maximal, thus $x_i = \frac{1}{3}$
 - thus $\alpha = \frac{3}{4}$



- The fairness of the chain tends towards the optimality (!)

$$\left\{ \frac{r_i(1500, n)}{r_1(1500, n)} \right\} \xrightarrow{n \rightarrow \infty} \left\{ \frac{x_i(\alpha^e(n), n)}{x_1(\alpha^e(n), n)} \right\}$$



Fairness issues
in a chain of
IEEE 802.11
emitters

B. Ducourthial
Y. Khaled,
S. Mottelet

802.11 issues

Chain of
stations

Simulations

Modeling

Analysis

Perspectives

- ① IEEE 802.11 research issues
- ② Case study : 3 pairs scenario
- ③ Simulations with many pairs
- ④ Modeling
- ⑤ Analysis
- ⑥ Perspectives for the fairness improvement



Perspectives for the fairness improvement

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- Sending a message of s bytes at d Mbits/s

sender S_i		receiver R_i	
DIFS or EIFS	50 or 364 μs		
aSlotTime \times CW \times 0.5	310 μs		
RTS	304 μs	SIFS	10 μs
		CTS	352 μs
SIFS	10 μs		
header and preamble (PHY)	192 μs		
s data bytes (MAC)	$8 \times s/d$ μs	SIFS	10 μs
		ACK	304 μs



Perspectives for the fairness improvement

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- Ratio between proportion α and packet's size s

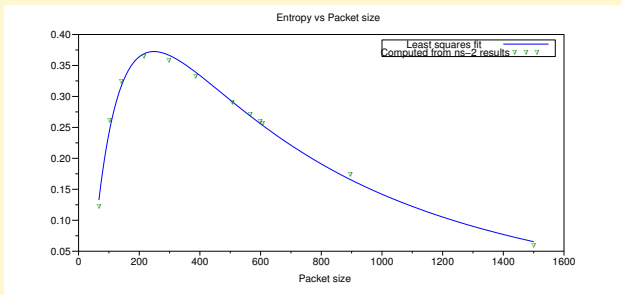
$$\alpha = \frac{496 + \frac{8s}{d}}{1492 + \frac{8s}{d}}$$

Perspectives for the fairness improvement

- Sending a message of s bytes at d Mbits/s
- Ratio between proportion α and packet's size s

$$\alpha = \frac{496 + \frac{8s}{d}}{1492 + \frac{8s}{d}}$$

- Example in a 3 pairs chain
Packet's size variation with ns-2



- 3 pairs scenario
 - ↪ particular case of a more general scenario
- Simple modeling with a single parameter
 - ↪ proportion α of idle time usage
- Analytical study :
 - convergence proof
 - asymptotic phenomena
 - optimal proportion $\frac{3}{4}$
 - ↪ give a quarter of your time to your neighbors
 - the 802.11 chain tends towards the maximal entropy !
- Perspectives
 - modulate the packet's size to improve the fairness, for n fixed
 - to bring closer to the optimal proportion
 - using the model for other configurations

