Fairness issues in a chain of IEEE 802.11 emitters

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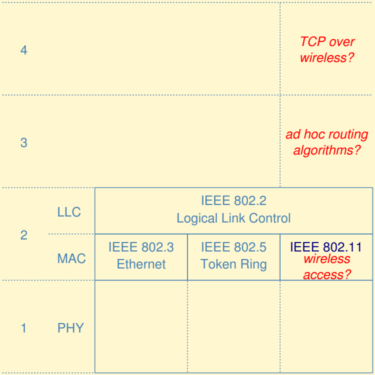
Plan

Outlines

Wireless network issues

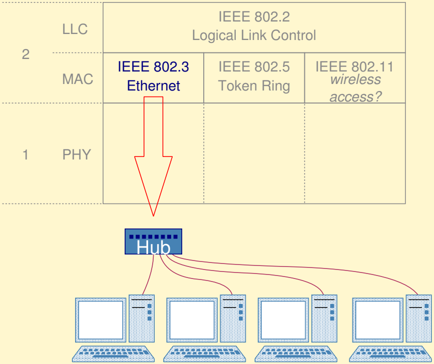


- Wireless networks research issues
  - data flow transport : cross layering... $\rightsquigarrow$ BTP
  - routing : OLSR, AODV... $\rightsquigarrow$ conditional transmissions
  - medium access : performance, new MAC, fairness...

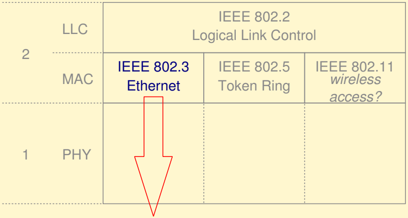
Medium access techniques

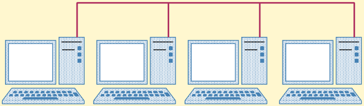
2	LLC	IEEE 802.2 Logical Link Control		
	MAC	IEEE 802.3 Ethernet	IEEE 802.5 Token Ring	IEEE 802.11 *wireless access?*
1	PHY			

Medium access techniques



Medium access techniques



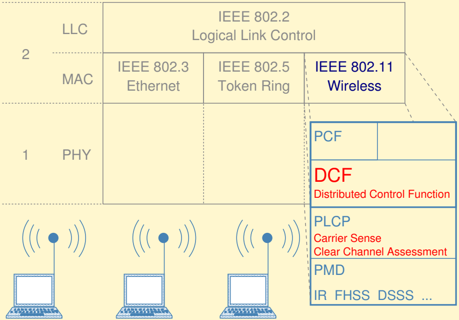


- CSMA/CD

  Carrier Sense Multiple Access / Collision Detection

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

Medium access techniques

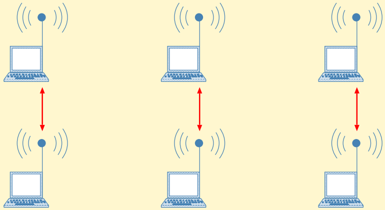


- CSMA/CA
  Carrier Sense Multiple Access / Collision Avoidance
  - a station listens to the medium (only neighbors)
  - waits for a fixed delay before sending
    Inter Frame Space, depends on the context
  - waits for a random delay if the medium is not idle
    decreases when the medium is idle during *aSlotTime*

Fairness issues in the IEEE 802.11 MAC

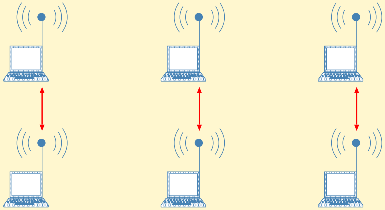
- IEEE 802.11 characteristics
  - collision detection
    a station cannot detect a collision by listening when it is sending
  - locallity phenomena
    a station may not ear all the other stations
- Consequences
  - preventive waiting (before sending)
    in the DCF procedure of the MAC layer
  - spatial unfairness

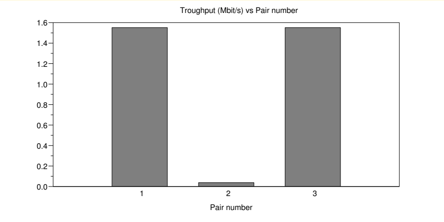
3 pairs scenario



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

3 pairs scenario





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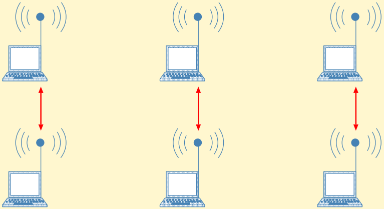
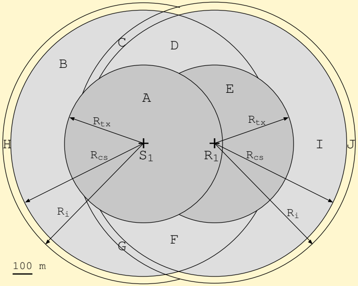


- our contributions
  - context extension (delays)
  - generalization to more than 3 pairs
  - non Markovian modeling
  - analytical study
  - applications to fairness improvements

Context extension

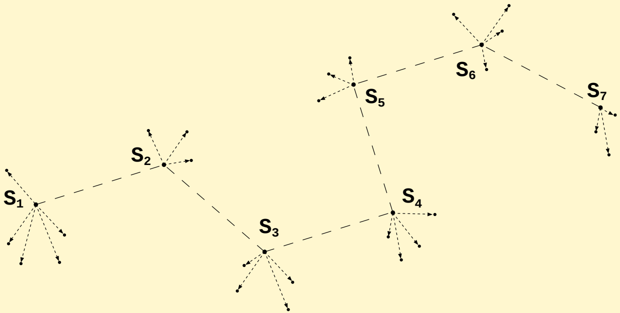
- Extended IFS not required

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



Context extension

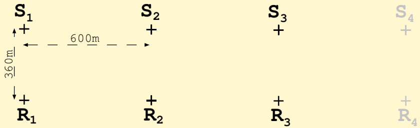
- Extended IFS not required
- Chain of emitters



Outlines

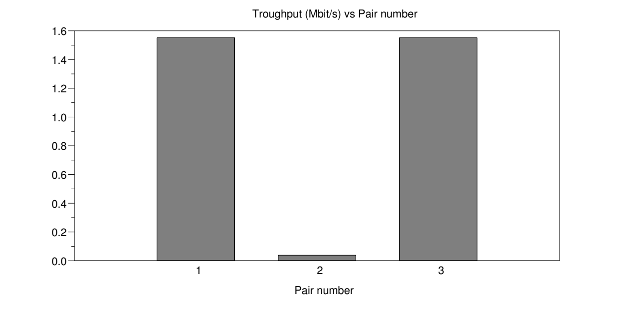
Generalization to more than 3 pairs

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



Generalization to more than 3 pairs

- simulation with ns-2
- parameters of a Lucent Orinoco 802.11b device in outdoor environment :
- results :
  - influence of the parity of n (number of pairs)
  - asymptotic phenomena



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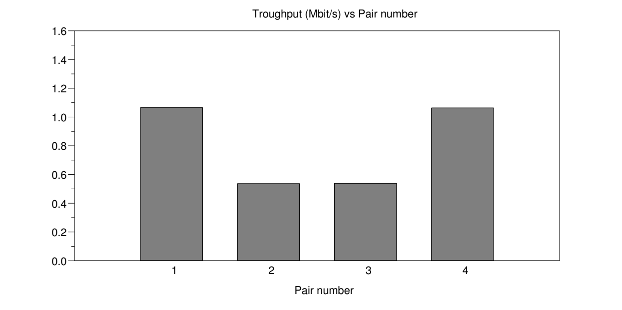

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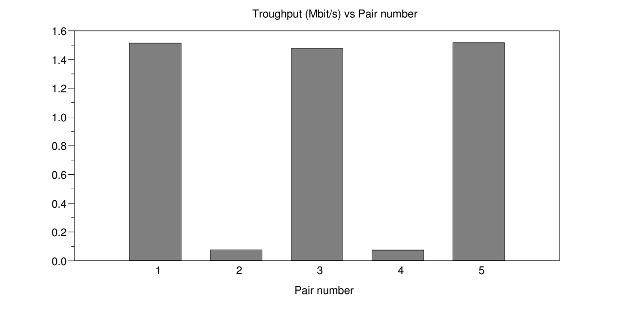

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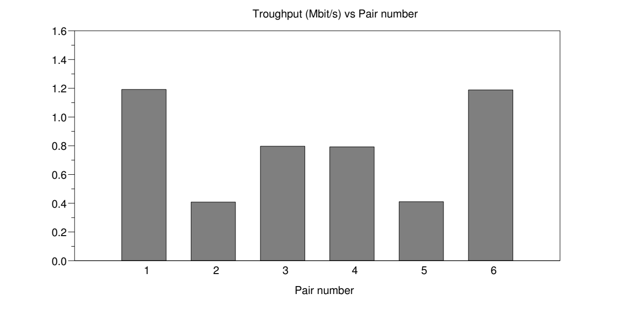

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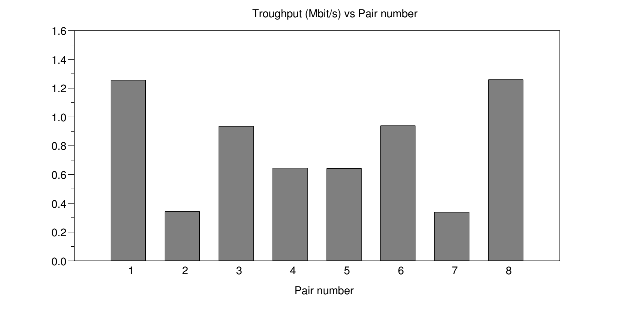

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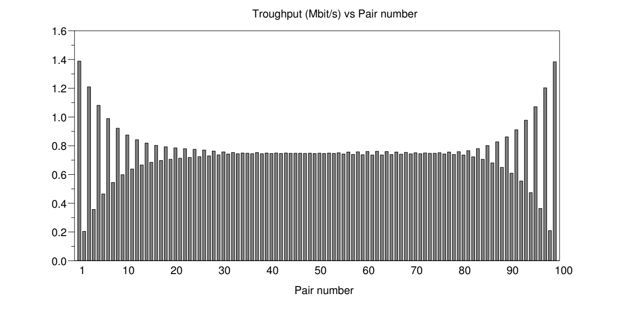
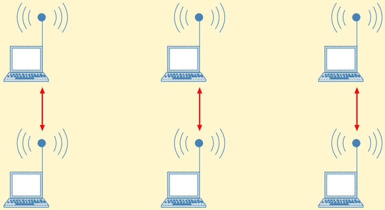


Outlines

Simple analytical model

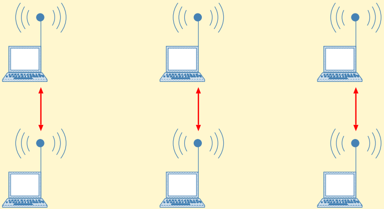


- Simple model, scalable (non Markovian)

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

- Intuitive explanation
  - listening before sending
    $\rightsquigarrow$ *a pair can send only if its neighbors are idle*
  - preventive waiting
    $\rightsquigarrow$ *a pair doesn't use all the idle time for sending*
    $\rightarrow$ *proportion* α, *with* $0 < \alpha < 1$

Simple analytical model



- Simple model, scalable (non Markovian)

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

- 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)

- 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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- least squares root identification of the families

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

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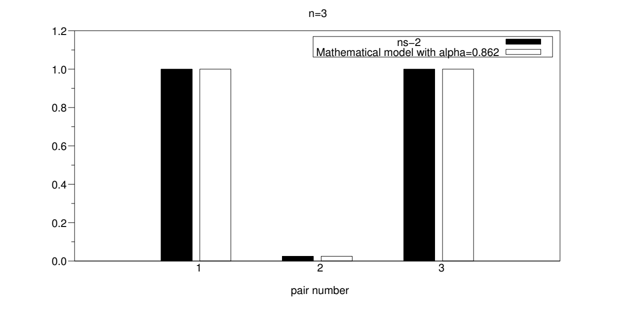
$\rightsquigarrow$ a single value of α allows to find the ns-2 results
fitting proportion $\alpha^f(s, n)$ $\qquad {}^f$ for fit

Model validation (2/2)

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



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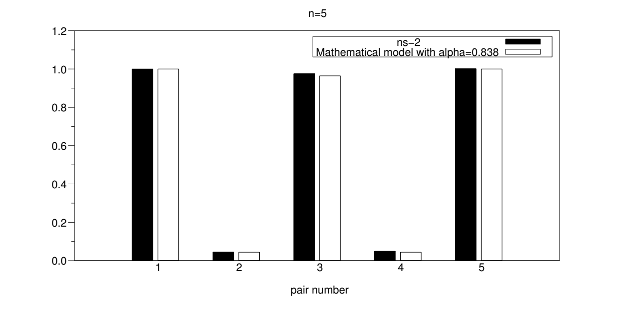

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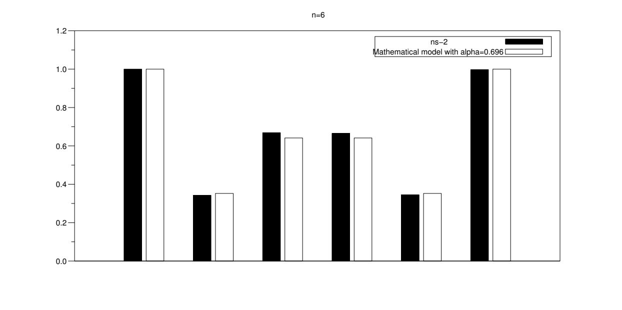

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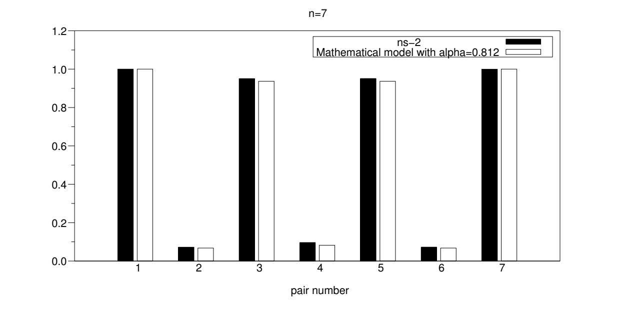
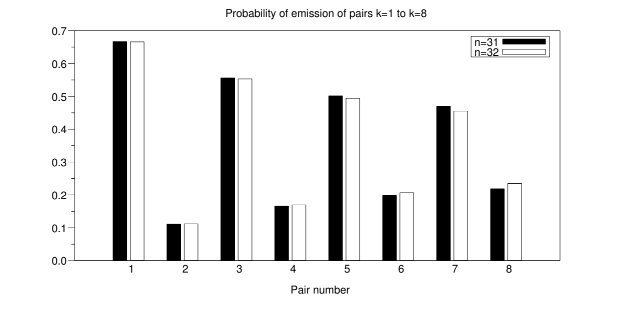


Outlines

Analysis (1/5)

- 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 $\alpha = 0.75$:

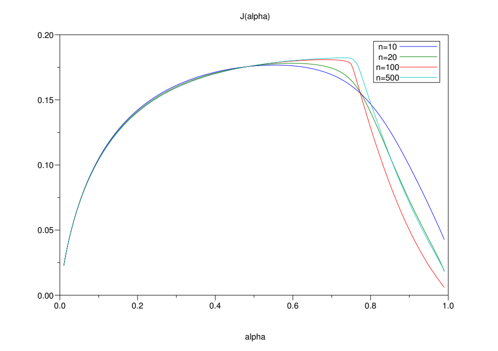


Analysis 2/5

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

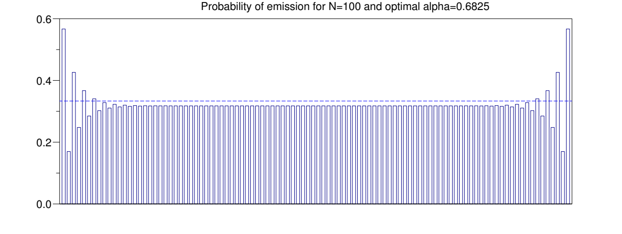
$$J(\alpha) = -1/n \sum_{i=1}^{n} x_i(\alpha, n) log(x_i(\alpha, n))$$

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



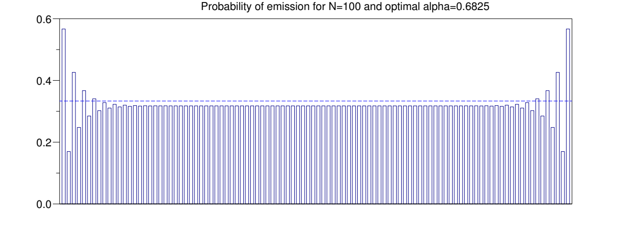
Analysis 3/5

- 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 $\frac{1}{3}$



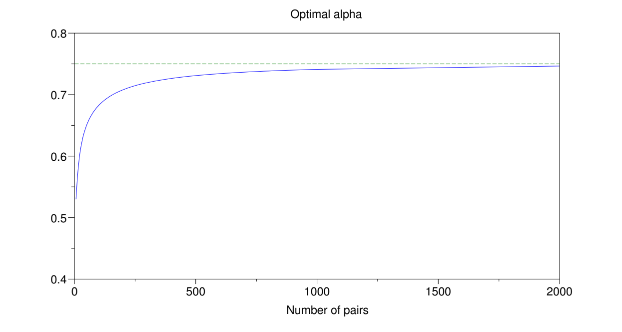
Analysis 3/5

- 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 $\frac{1}{3}$
  - 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}
    - $P(u_i < u_{i+1}, u_i < u_{i-1}) = \frac{1}{3}$



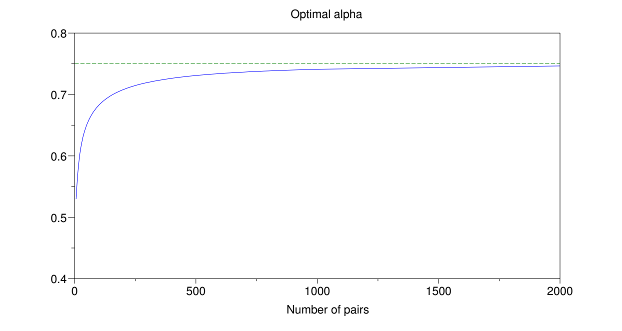
Analysis 4/5

- optimal proportion $\alpha^e(n) \xrightarrow{n\to\infty} 3/4$



Analysis 4/5

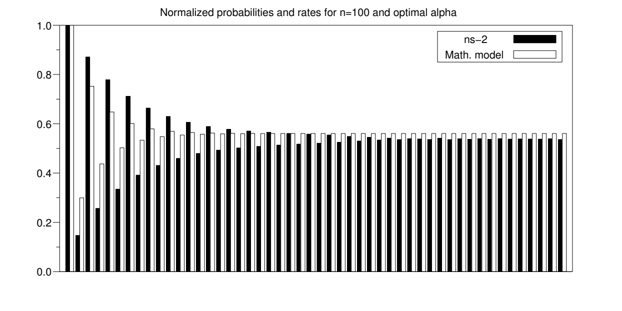
- optimal proportion $\alpha^e(n) \xrightarrow{n\to\infty} 3/4$
- Asympt. proportion $3/4 \leftrightarrow$ optim. probability $\frac{1}{3}$
  - infinite chain (or large loop)
  - the equations system becomes $x_i = \alpha(1 - x_i)^2$
  - the entropy is maximal, thus $x_i = \frac{1}{3}$
  - thus $\alpha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



Analysis 5/5

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

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



Outlines

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Perspectives for the fairness improvement

- Sending a message of s bytes at dMbits/s

sender S_i		receiver R_i	
DIFS or EIFS	50 or 364 μs		
aSlotTime $\times$ CW $\times 0.5$	310μs		
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

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- Ratio between proportion α and packet's size s

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

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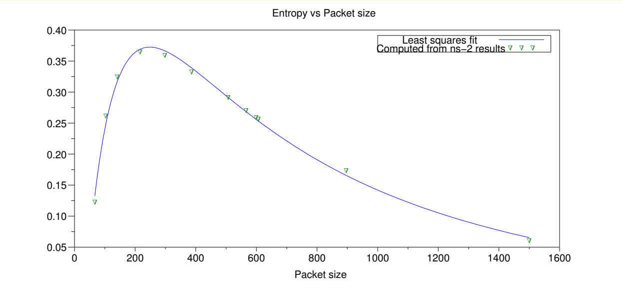
- Example in a 3 pairs chain

  Packet's size variation with ns-2



Conclusion

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