Aperiodic traffic in response time analyses with adjustable safety level

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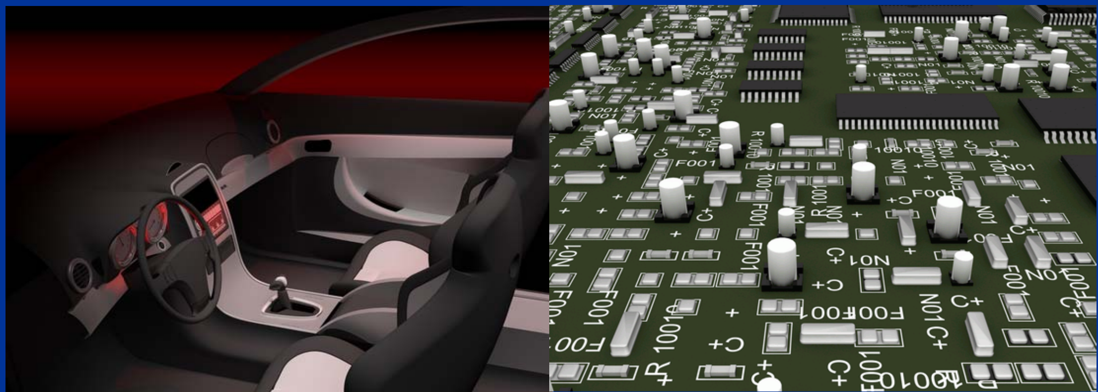

ETFA’2009, Palma

24/09/2009

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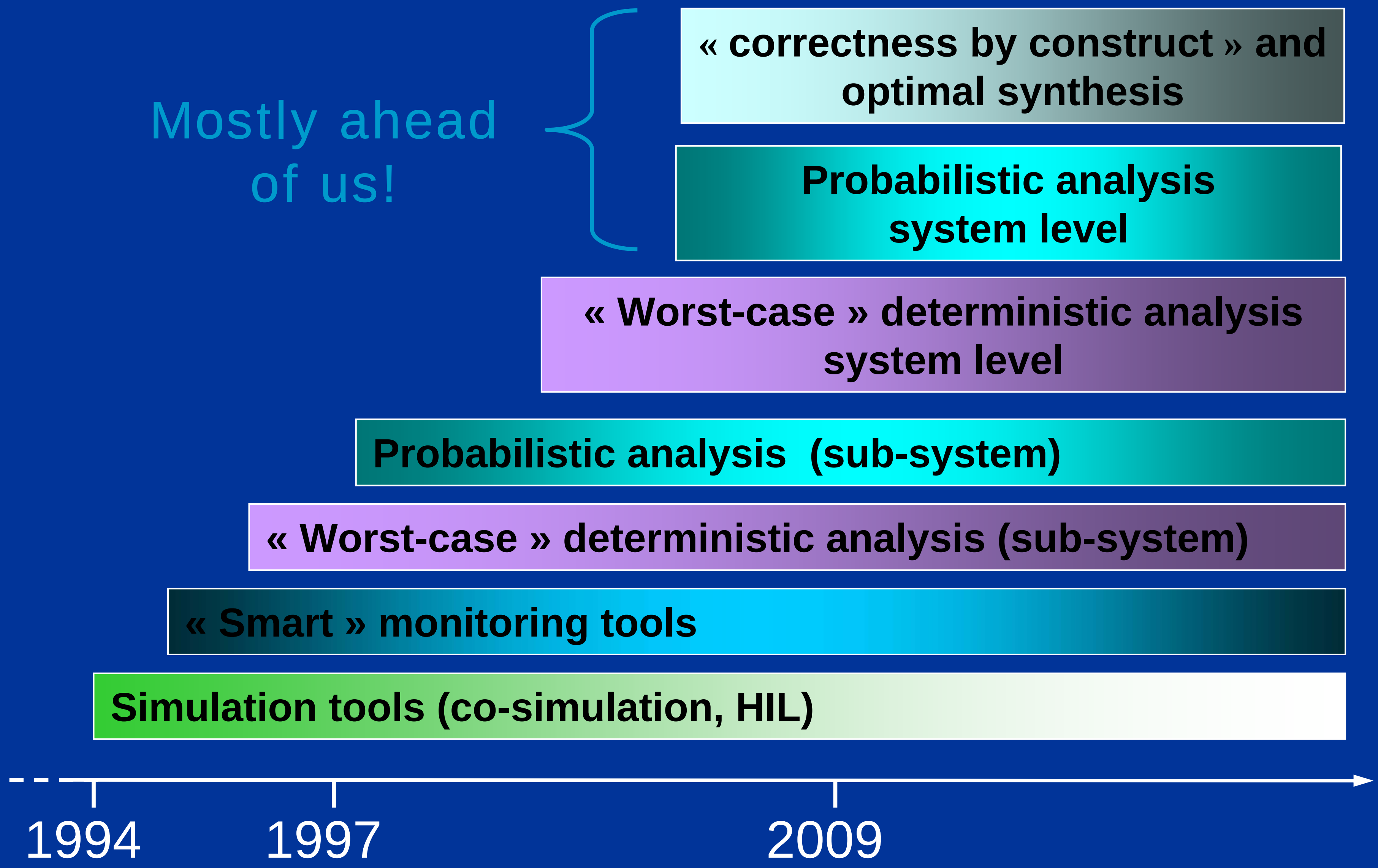
Complexity Mastered

Validation is a key activity in automotive systems design
Personal view on the developments



Probabilistic analysis is needed

- Systems are not designed for the worst-case (provided it is rare enough!)
- Reliability/Safety are naturally expressed and assessed in terms of probability (e.g. < 10^-9 per hour)
- Deterministic assumptions are sometimes unrealistic or too pessimistic, e.g.:
  - Worst-Case Execution Time on modern platforms,
  - Aperiodic activities: ISR, frame reception,
  - …
- Faults/errors are not deterministic (and better modeled probabilistically)

Accounting for the aperiodic traffic

- Transmission patterns can hardly be characterized: purely aperiodic, mixed periodic/aperiodic, etc
- Aperiodic frames do jeopardize RT constraints
- Few approaches in the litterature:
  - deterministic approaches, such as sporadic, generally lead to unusable results (e.g., $\rho>1$)
  - Average case probabilistic approach not suited to dependability-constrained systems
  - Probabilistic approaches with safety adjustable level, see paper ref[6] and ref[7]

Approach advocated here

1) Measurements / data cleaning
2) Modeling aperiodic traffic arrival process
3) Deriving aperiodic Work Arrival Process (WAF)
4) Integrating aperiodic WAF into schedulability analysis

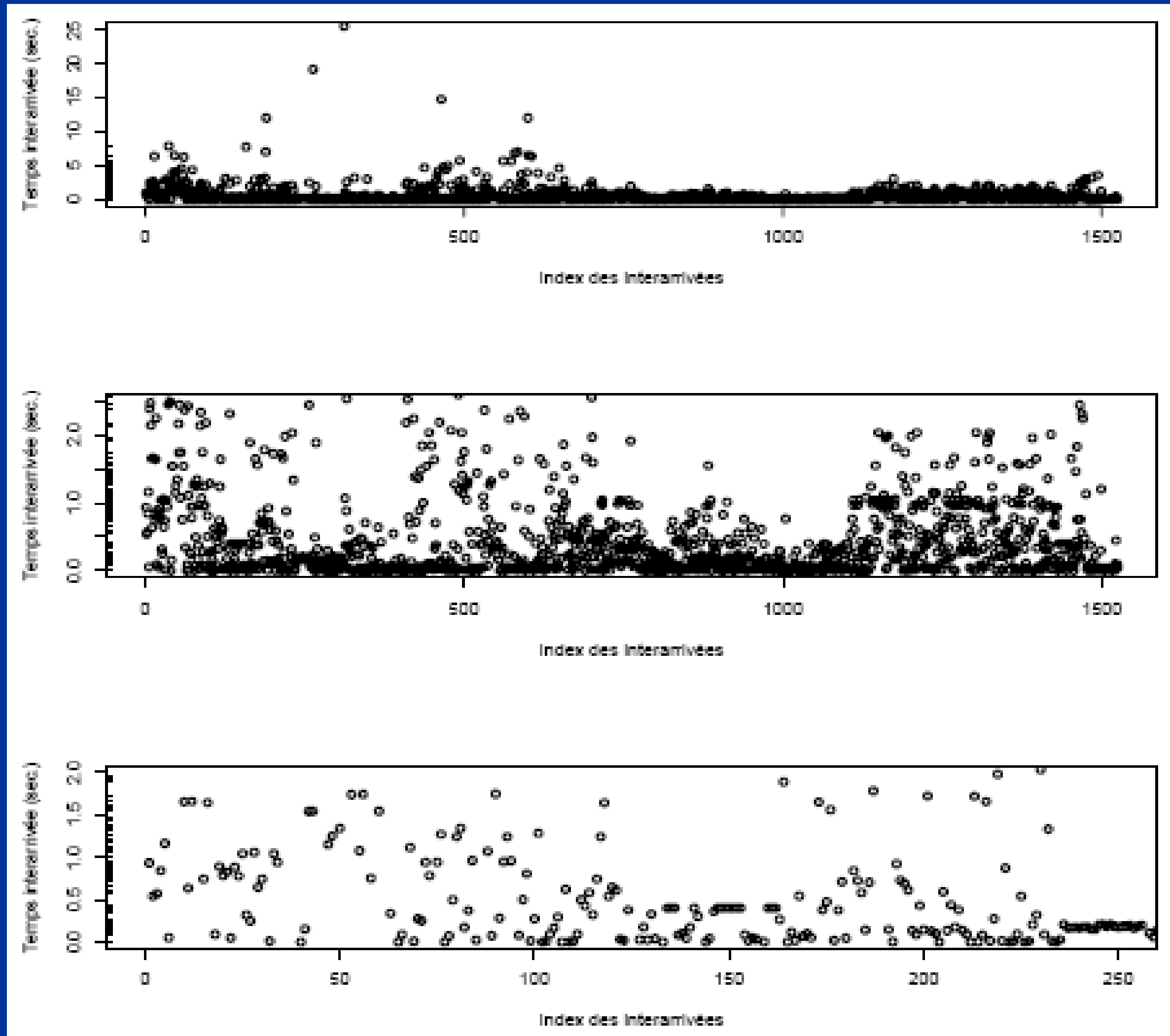
Data trace analysis

y: aperiodic interarrival times – x: index of interarrivals

ZOOM +

↓

Approximate because what is seen on the bus is not the actual arrival process at ECU level! can be handled



x : [0-1500]
y : [0-25]

x : [0-1500]
y : [0-2.5]

x : [0-250]
y : [0-2]

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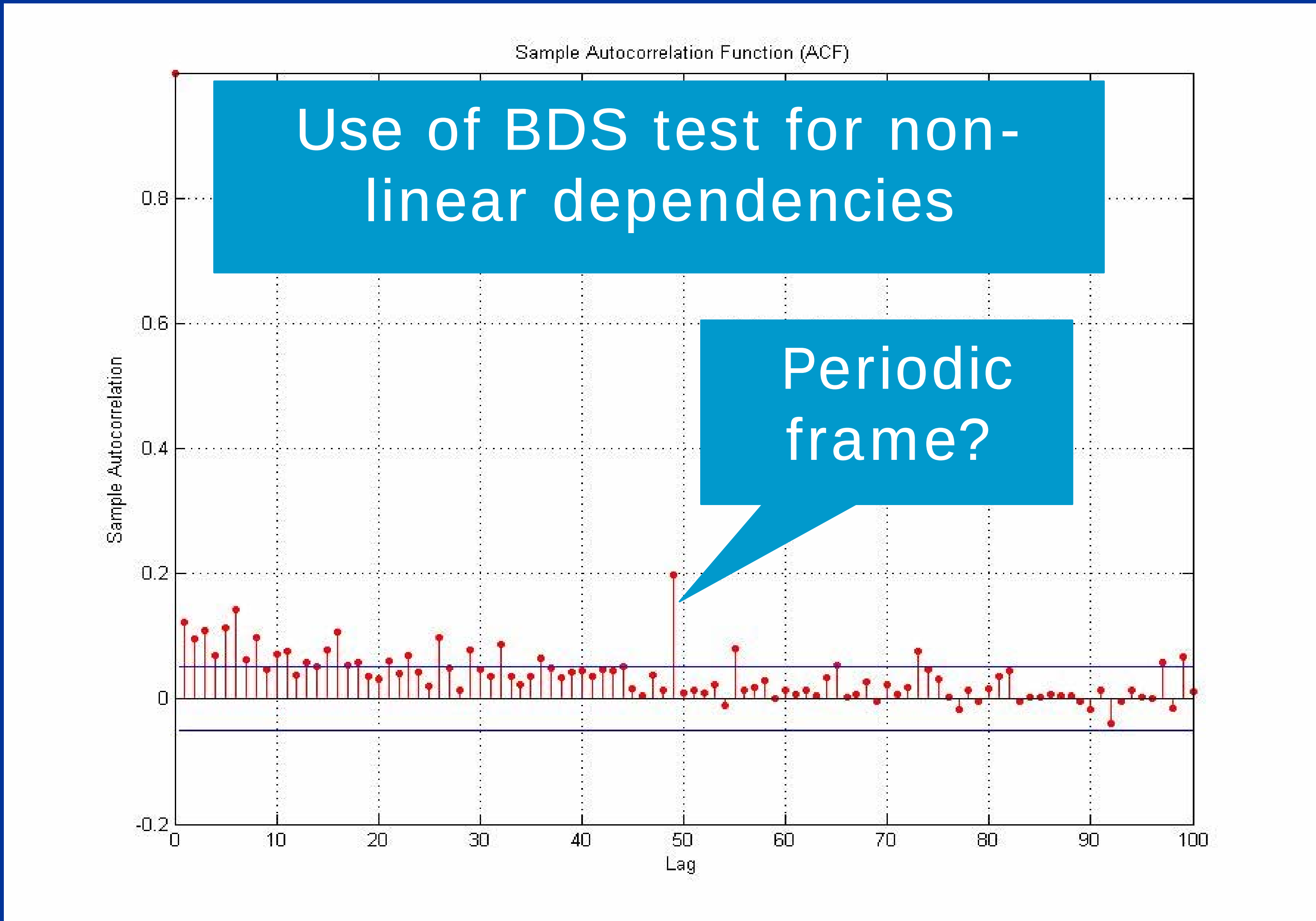
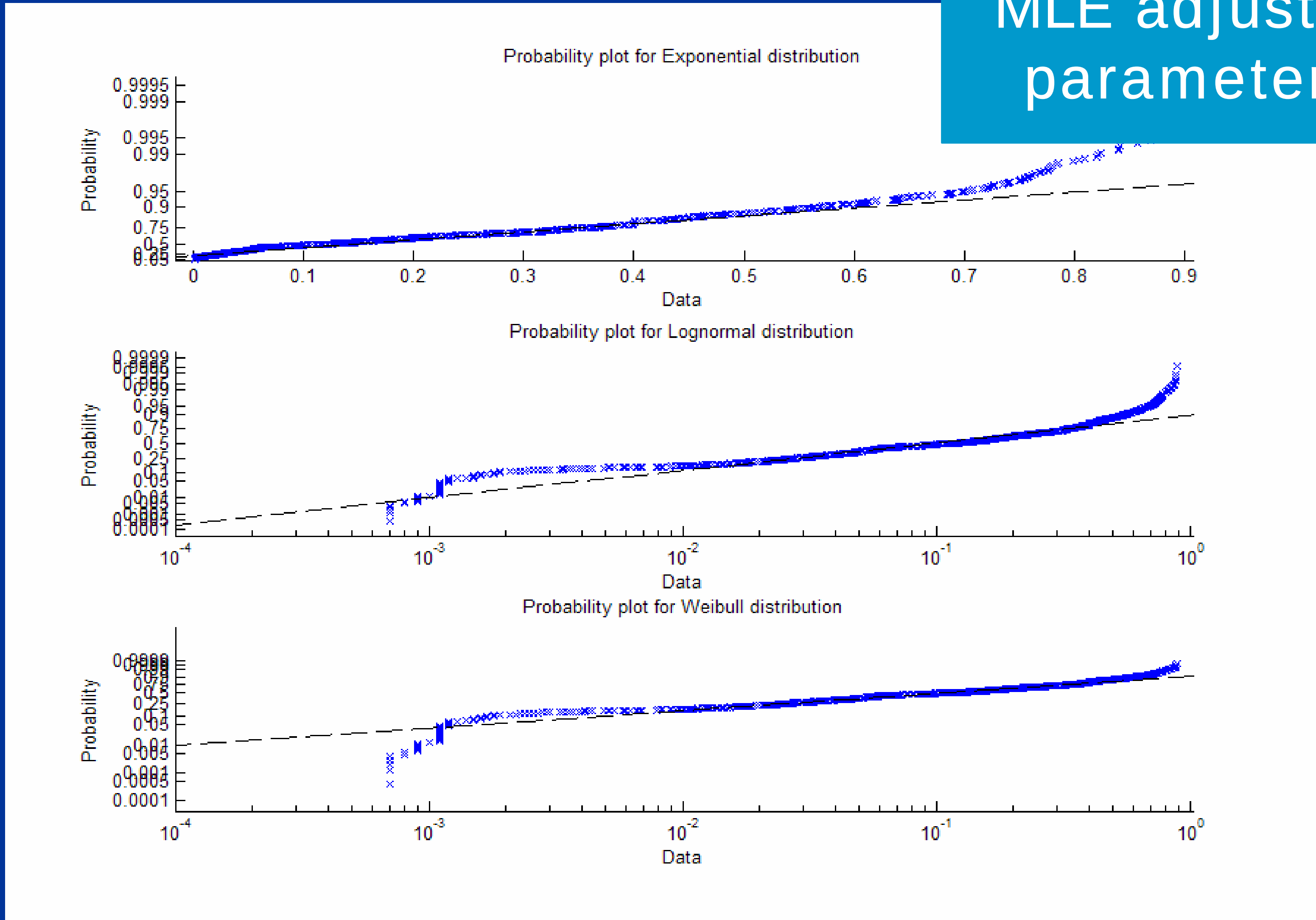
Question: are interarrival times i.i.d. ?



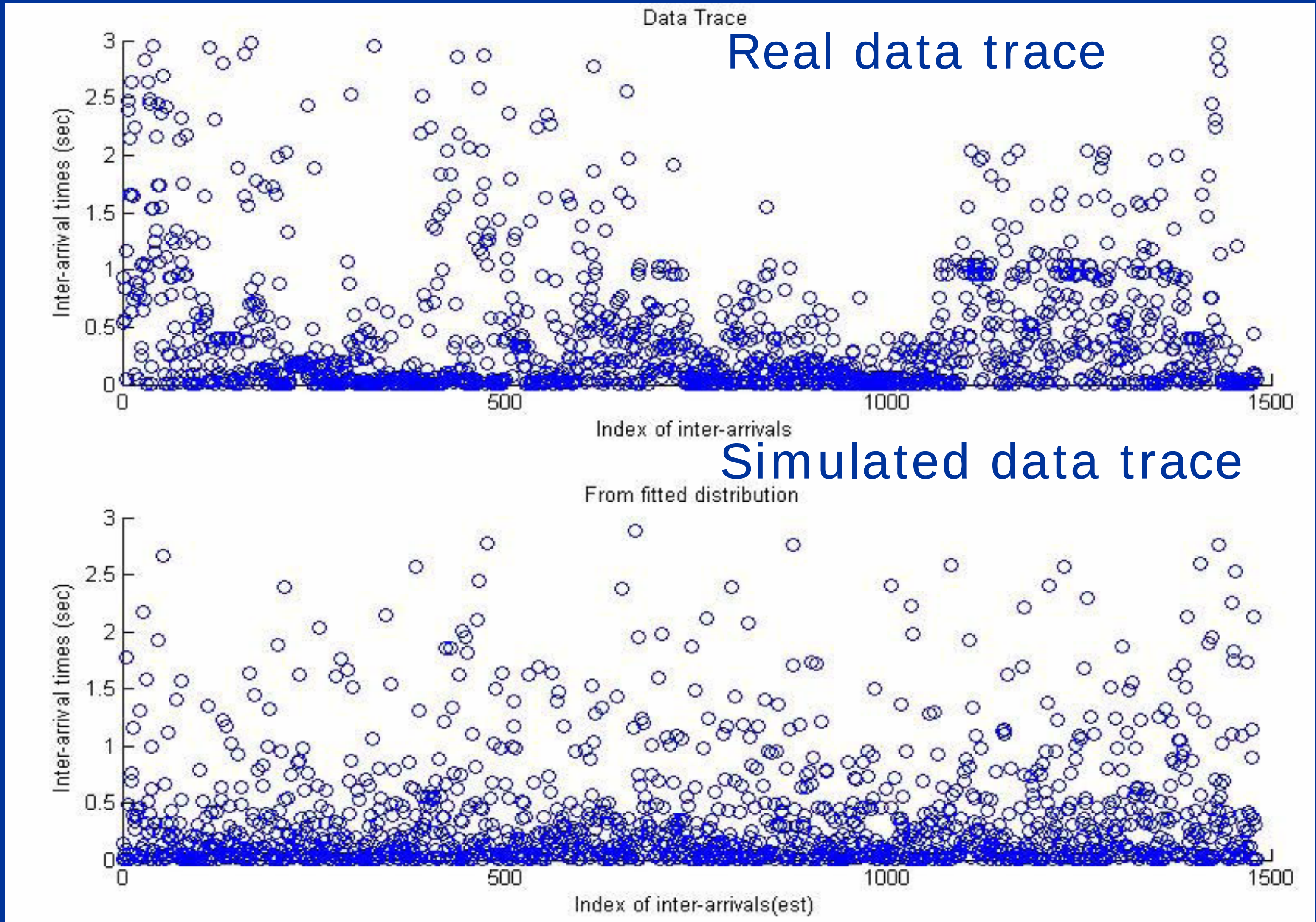
Distribution fitting for aperiodic interarrival : 3 candidates here

MLE adjusted parameters

Kolmo. Smi. and $\chi 2$ tests to confirm visual impression



Captured data trace VS random trace generated with MLE-fitted Weibull



Deriving the aperiodic WAF

- S(t) : aperiodic WAF
- X(t) : stochastic process which counts the number of aperiodic frames in time interval t
- "smallest" S(t) such that the probability of X(t) being larger than or equal to S(t) is lower than a threshold α

$$\hat{S}(t) = \min\{S(t) \mid Pr[X(t) \geq S(t)] \leq \alpha\}$$

By simulation, numerical approximation or analysis (simplest cases such as exp.)

Design choice: e.g., 10^{-9}

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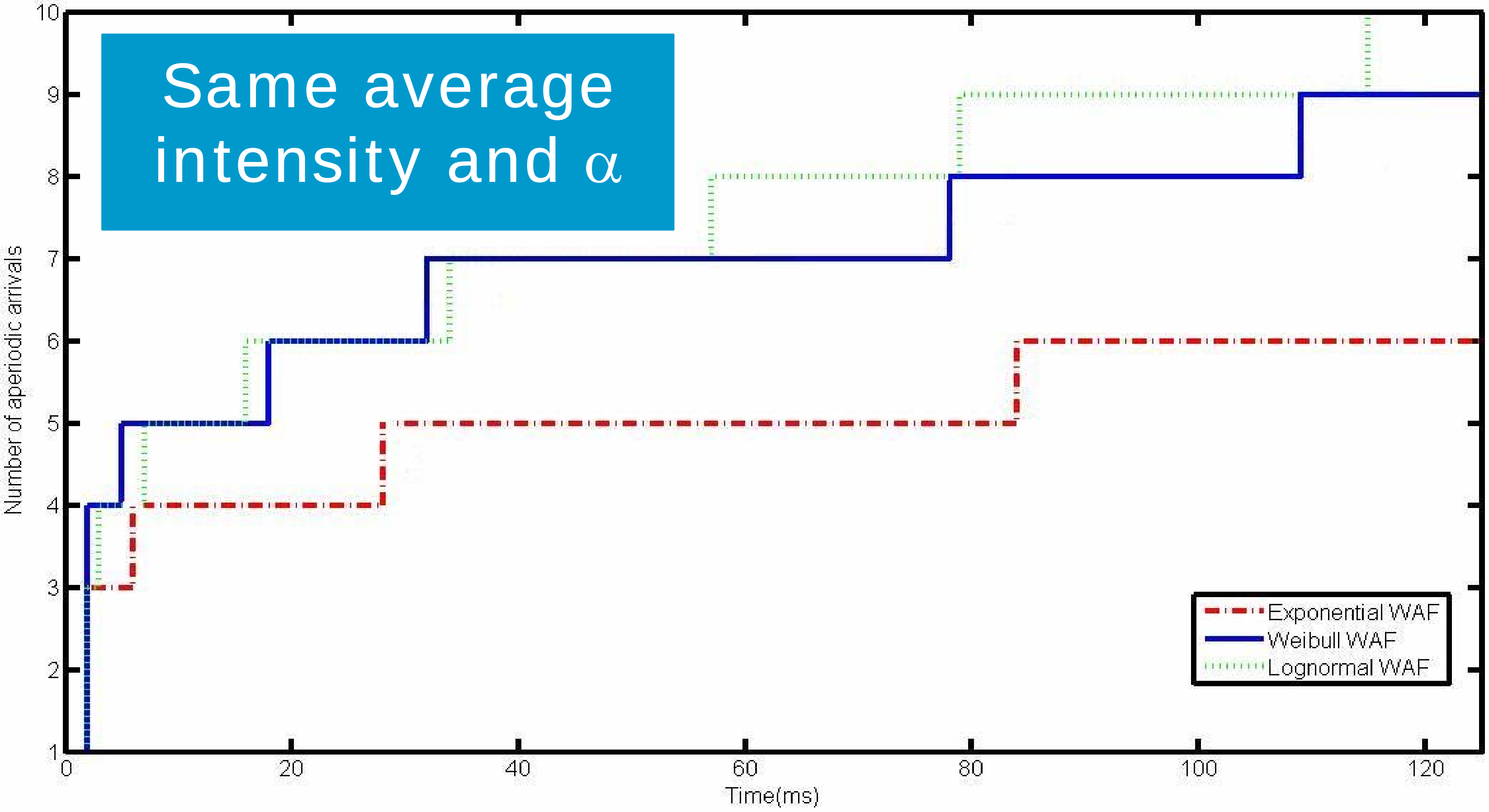
Aperiodic WAF depends on the underlying interarrival distribution



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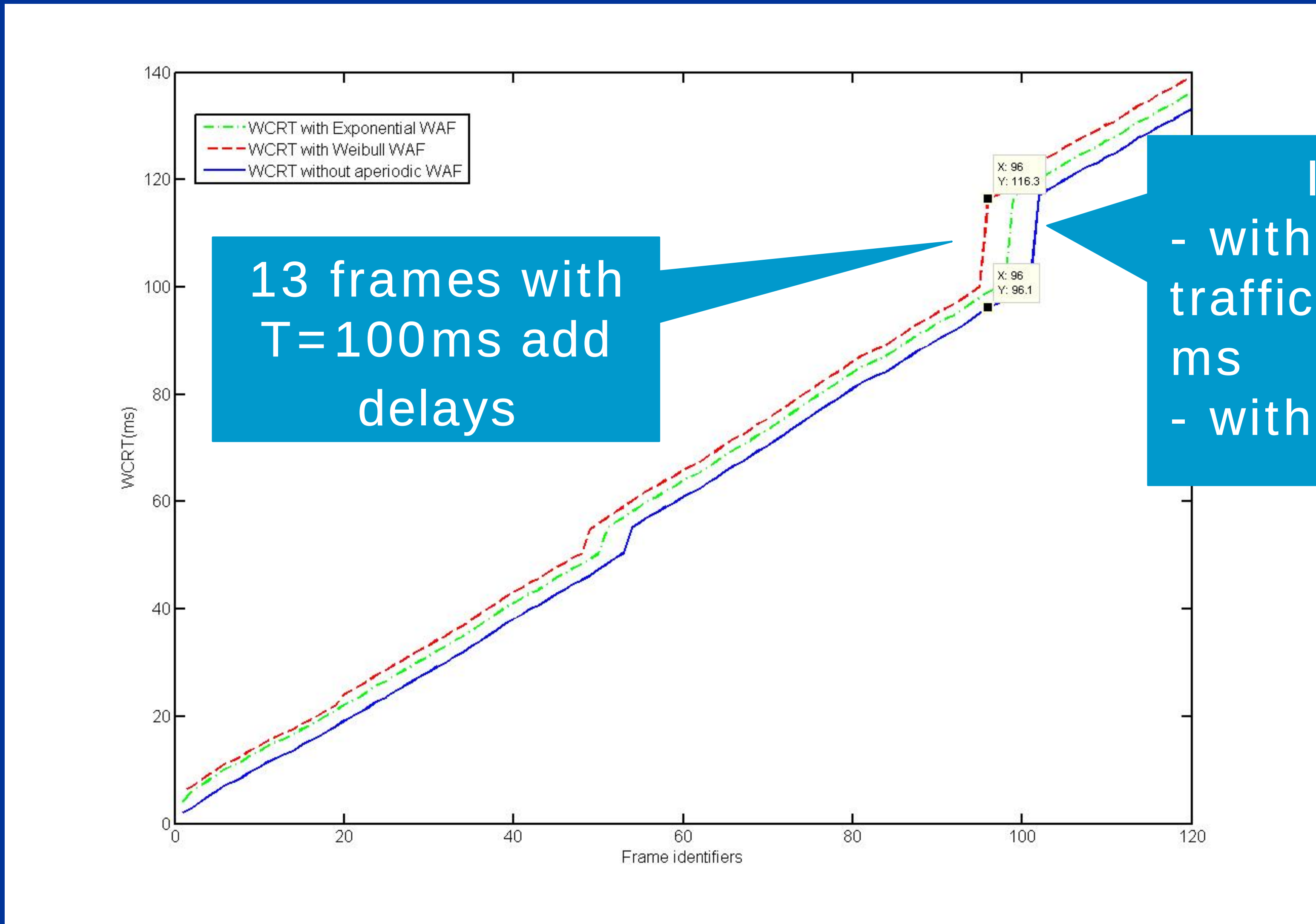
Case-study on a typical body network

- Body network benchmark generated using GPL-licensed Netcarbench
- Characteristics:
  - 125kbps, 16 ECUs, 105 CAN frames with deadlines equal to periods and 1 to 8 bytes of data.
  - Total periodic load is equal to 41%
- NETCAR-Analyzer for WCRT computation
- 3% aperiodic traffic
- 7 byte aperiodic frames
- $\alpha = 10^{-4}$

Worst-case response times with/out aperiodic traffic (3%)



13 frames with T=100ms add delays

Id96:
- with aperiodic traffic: 116.3 ms
- without: 96ms

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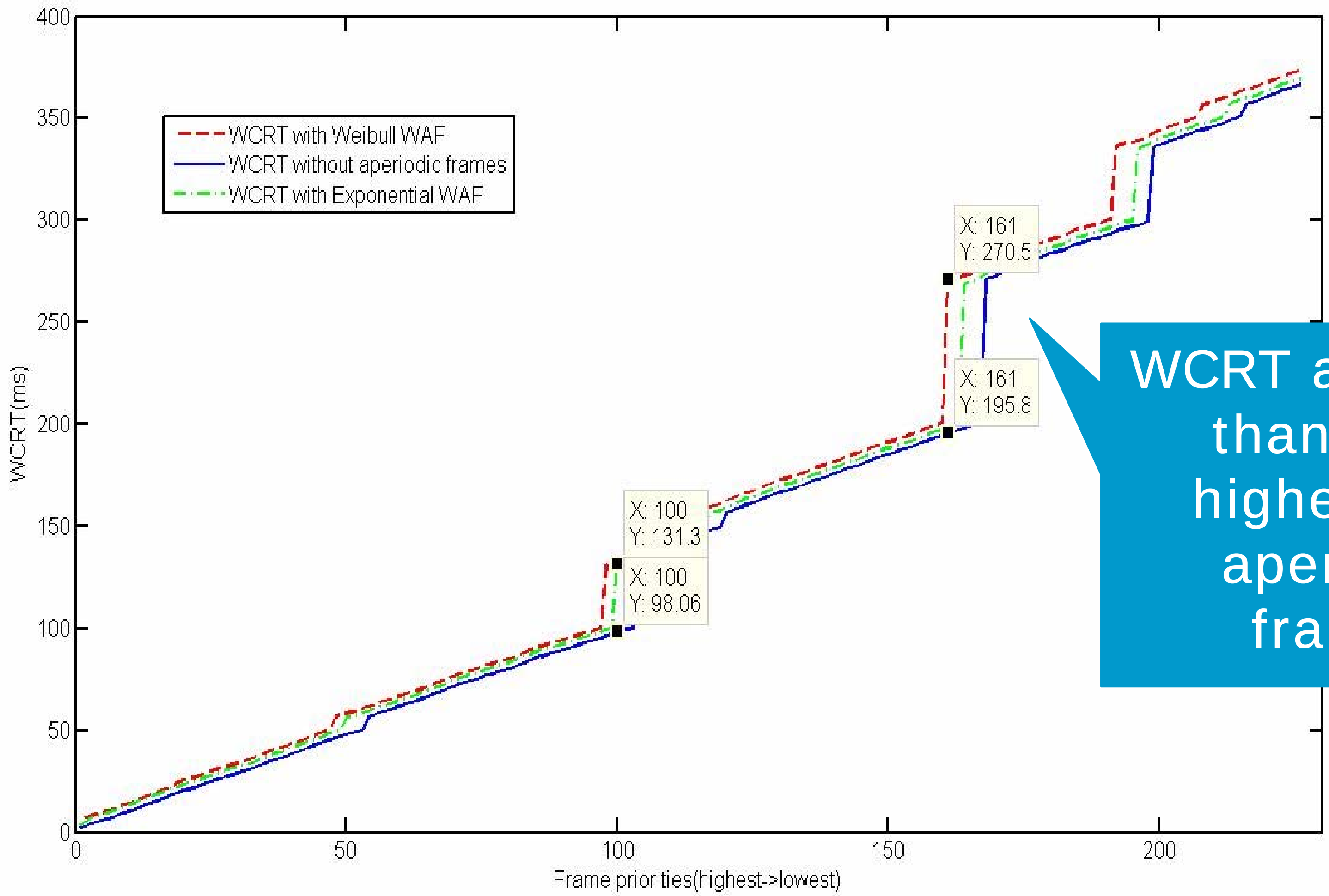
On a more loaded network…



WCRT are more than 30% higher with aperiodic frames

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Observations

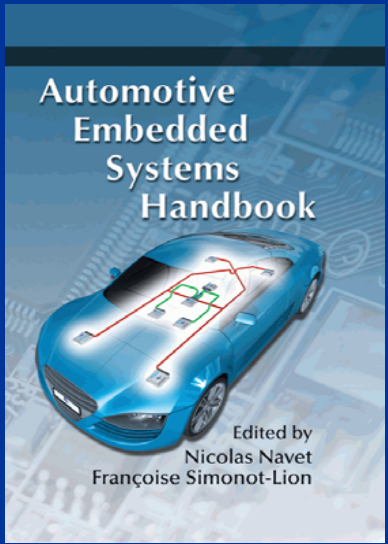
- In this context where the periodic load is relatively small and the aperiodic traffic is limited (3%) one observes:
- aperiodic traffic significantly impacts the worst-case response times of the periodic frames (more than +30% sometimes).
- the exact model of the aperiodic traffic plays some role
- depends on the priority of the aperiodic frames (working on this)
- Measured arrival time on bus at which the frames started to be transmitted can be different than time at which the transmission requests were issued

Conclusion

- Chosen dependability requirements are met while pessimism kept to minimum:
  - Practical approach
  - Real data are required
  - Can be extended to the non i.i.d. case (not needed here)
- What is needed now is a system level approach that
  - Can handle arbitrary activation processes
  - goes beyond the i.i.d. case (for dependability assessment)

References

References (1/2)



Automotive Embedded Systems - General

[1] N. Navet, F. Simonot-Lion, editors, The Automotive Embedded Systems Handbook, Industrial Information Technology series, CRC Press / Taylor and Francis, ISBN 978-0849380266, December 2008.

[2] P. Wallin, Axelsson, A Case Study of Issues Related to Automotive E/E System Architecture Development, IEEE International Conference and Workshop on the Engineering of Computer Based Systems, 2008.

[3] H. Hansson, M. Nolin, T. Nolte, Beating the Automotive Code Complexity Challenge: Components, Models and Tools, National Workshop on High-Confidence Automotive Cyber-Physical Systems, 2008.

Dependability / probabilistic framework

[4] N. Navet, H. Perrault, “Mécanismes de protection dans AUTOSAR OS”, RTS Embedded Systems 2009 (RTS’09), Paris, April 2009.

[5] D. Khan, N. Navet, B. Bavoux, J. Migge, “Aperiodic Traffic in Response Time Analyses with Adjustable Safety Level“, IEEE ETFA2009, Mallorca, Spain, September 2009.

[6] N. Navet, Y-Q. Song, F. Simonot, “Worst-Case Deadline Failure Probability in Real-Time Applications Distributed over CAN (Controller Area Network)“, Journal of Systems Architecture, Elsevier Science, vol. 46, n°7, 2000.

[7] A. Burns, G. Bernat, I. Broster, A probabilistic framework for schedulability analysi, Third International Conference on Embedded Software (EMSOFT 2003), 2003.

Questions / feedback ?

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