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Analysis of Performance Variation in 16 nm FinFET FPGA Devices

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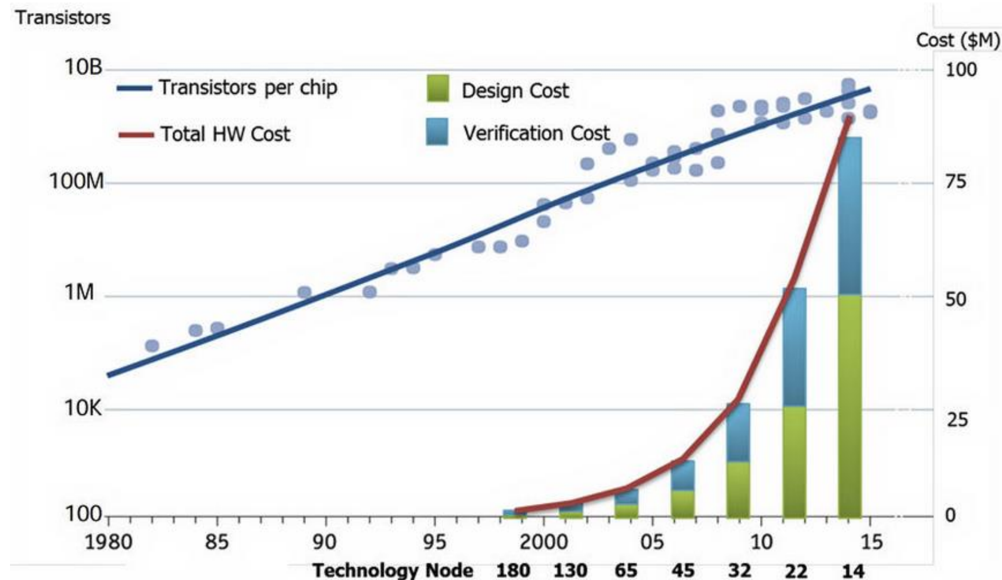
Introduction

- Further transistor scaling has become extremely challenging



Source: DARPA, http://www.ispd.cc/slides/2018/k2.pdf

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- Increased **process variability**
  - great **deviations in electrical properties** of transistors
    - switching activity, leakage current
- Global & pessimistic operation guard-bands are employed
  - **performance loss**, i.e., maximum frequency, power consumption

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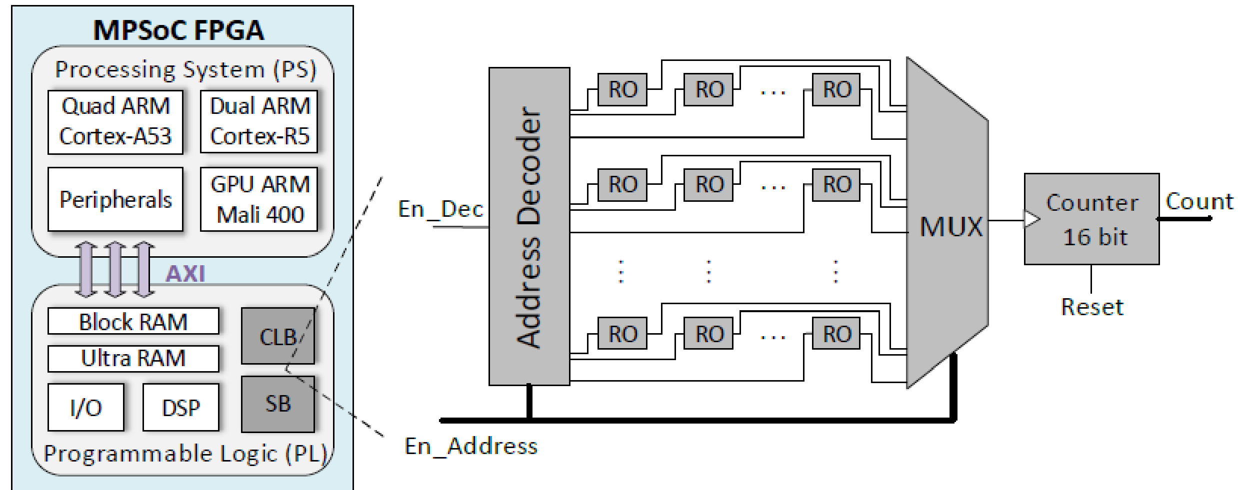
➢ We evaluate the performance variation in 16nm FPGAs

Evaluation Methodology: Variability Maps



- Deploy a network of **soft macro sensors**

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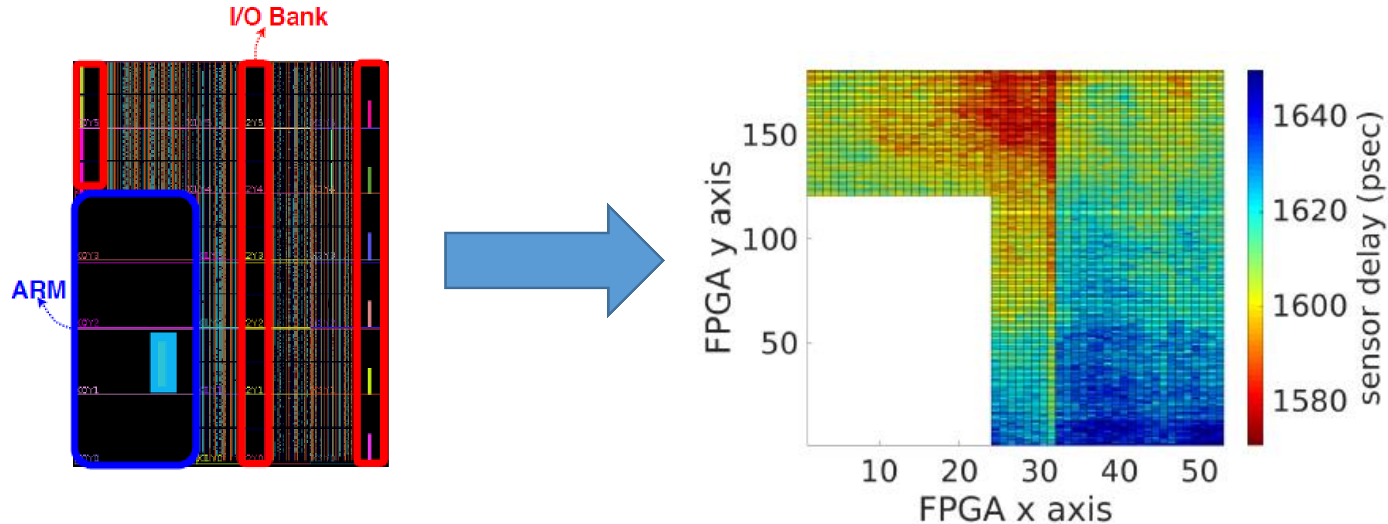
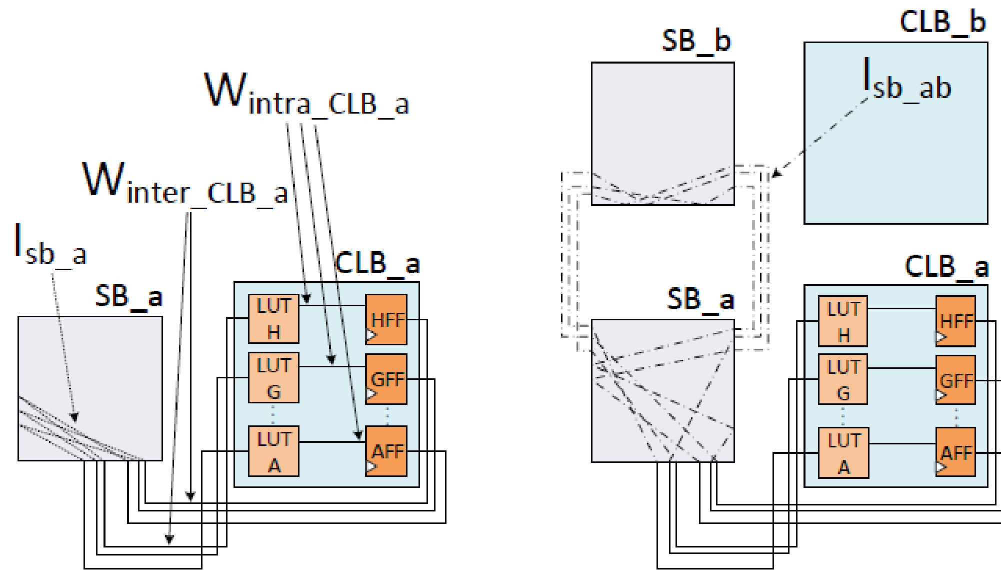


- Deploy a network of **soft macro sensors**
- Compare the delay among the sensors:
  - inside the chip → **intra-die variation**
  - among the chips→ **inter-die variation**

Evaluation Methodology: Sensor Design

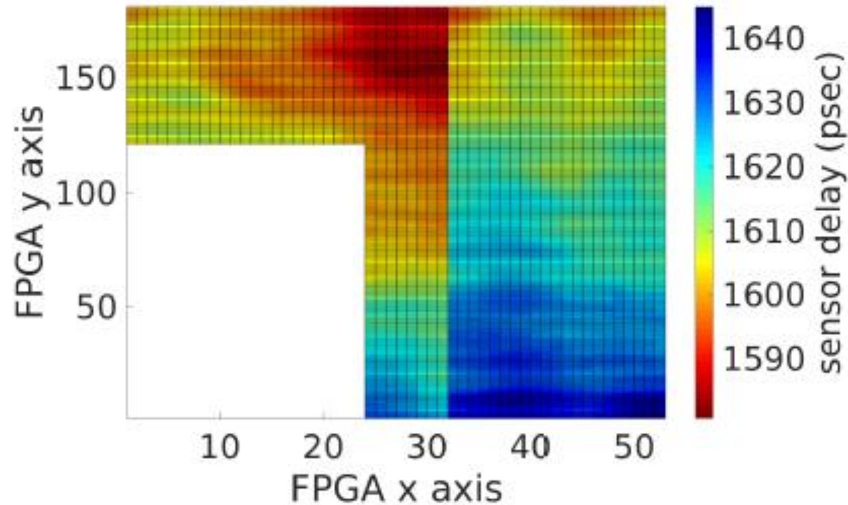
- Variety of **ring oscillator** (RO) sensors
  - Different utilization ratios of **logic & interconnect** resources



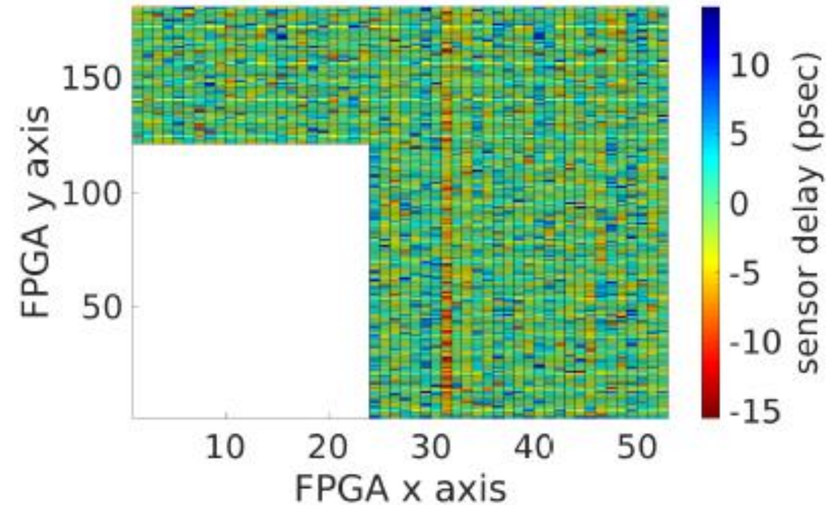
Evaluation Methodology: Decouple of Variability

- $T_d = T_d^S + T_d^R$

Systematic



Stochastic



Results: Total Variability Evaluation

- Four identical Zynq XCZU7EV FPGAs
  - **7.3% intra-die variation**
  - **8.3% inter-die variation**

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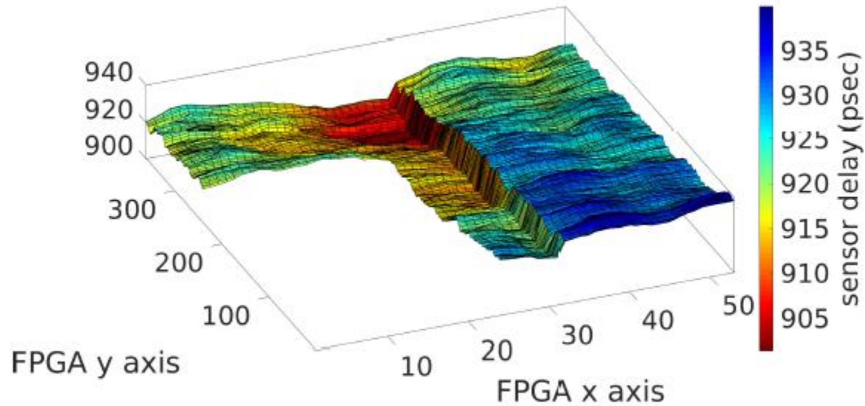
- **Interconnects** present **lower variation**
  - e.g., 3.5% for intra-die

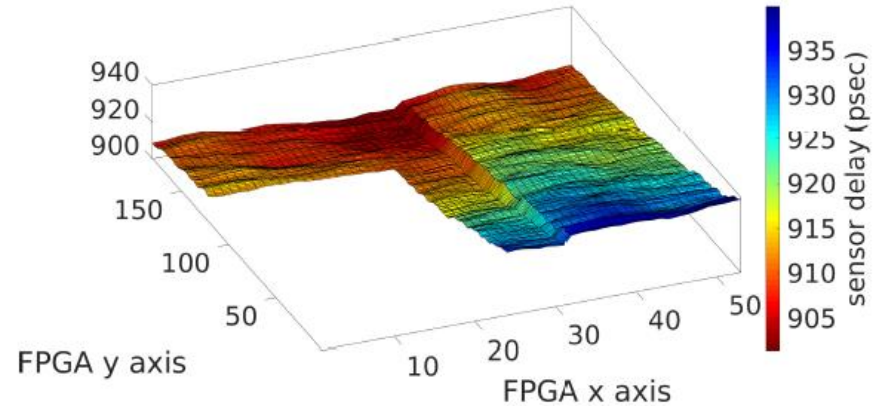
- **More pessimistic guard-bands** for interconnects

Results: Systematic Variability

Logic (mainly logic gates)



Interconnect (mainly wires)



- **Correlation weakens** as logic/interconnect ratio changes, e.g., $p = 0.6$
- **High perf. estimation error** between different areas, e.g., 3.45%

Results: Variability Under Diverse Conditions

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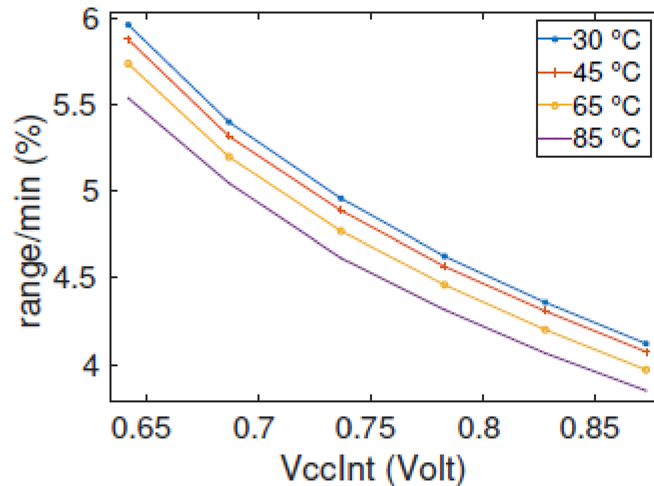

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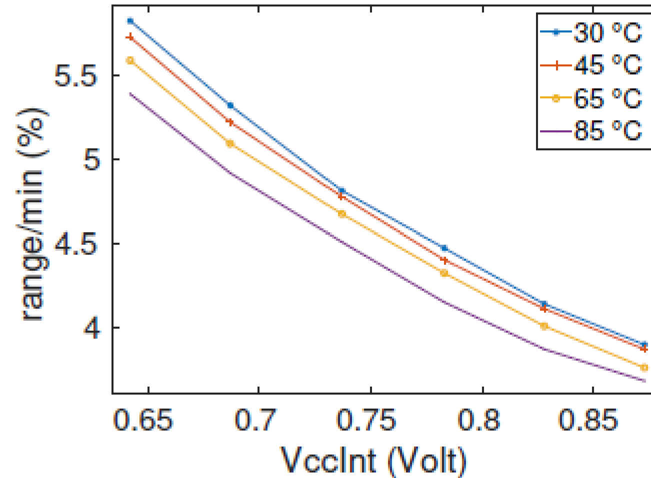

- **Increase** with **voltage reduction**, **decrease** with **temperature elevation**
- **Increased performance estimation error**, i.e., 3.6%

Conclusion

1. Study of performance **variation in 16nm FPGAs** in a multifaceted way
   - various sensors, operating conditions and decoupling of variability
   - up to **10% intra-die** and **12% inter-die** variation

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3. Insights for the implementation of **more accurate mitigation methods/tools**

Thank you!