# System Level Power Estimation of System-on-Chip Interconnects in Consideration of Transition Activity and Crosstalk

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# Outline

- Motivation and Basics
- High Level Power Estimation of Interconnects
  - Dynamic power consumption and Crosstalk
  - Data stream analysis
  - Results
- Conclusion / Outlook

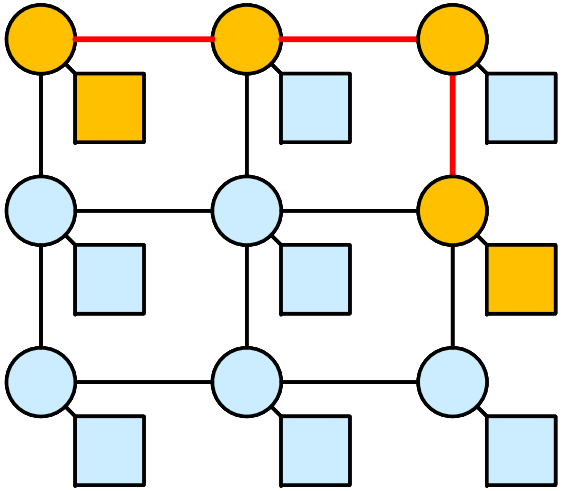
# Motivation

- Performance
- Energy
- Reliability

- Energy estimation is needed in every design step to meet constraints of all three aspects

# Basics – Energy in NoCs

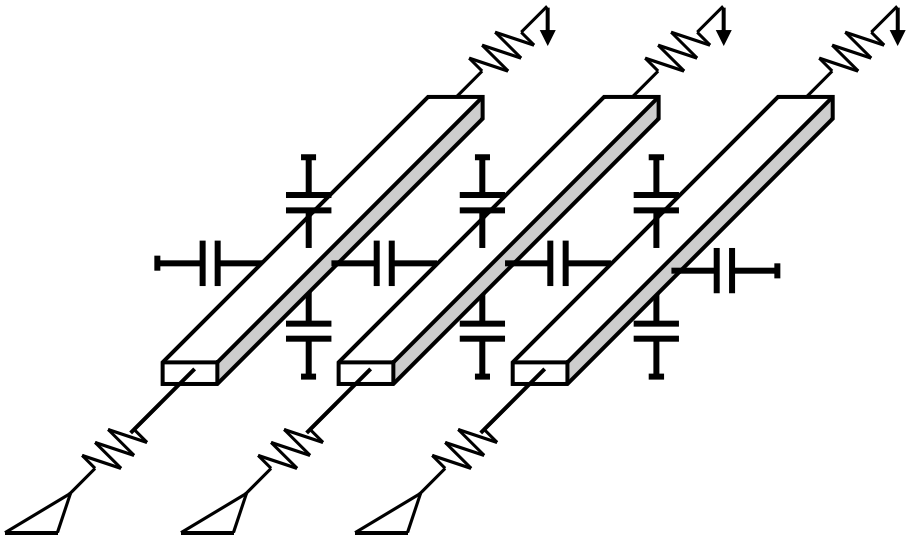
- NoC: IP-Core, Router, Link



- Energy Estimation of
  - IP-Core
  - Router
  - Link

# Dynamic power consumption and Crosstalk

- Link -> Wires
  - R, L, Capacitances (ground, top, fringe, **coupling**)



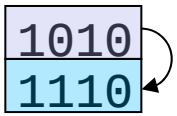
Crosstalk:

If wire i is driven from 0 to 1, Miller Coupling Factor (MCF) depends on changes of i+1 and i-1:

| | 0→0 | 0→1 | 1→0 | 1→1 |
|---|---|---|---|---|
| 0→0 | 2 | 1 | 3 | 2 |
| 0→1 | 1 | 0 | 2 | 1 |
| 1→0 | 3 | 2 | 4 | 3 |
| 1→1 | 2 | 1 | 3 | 2 |

# Data Stream Analysis

- Data stream based estimation tool
- Summing up transitions and MCFs of each bit in each word
- Getting signal statistics and energy estimations




0010
0110
1101
1100
0100
1011

- Using different data (video, music, text, random)
- Tracing signals of a H264 SOC (system verilog design) to obtain signal statistics

Counting Transitions
Counting MCF (Crosstalk)

# Energy Estimation

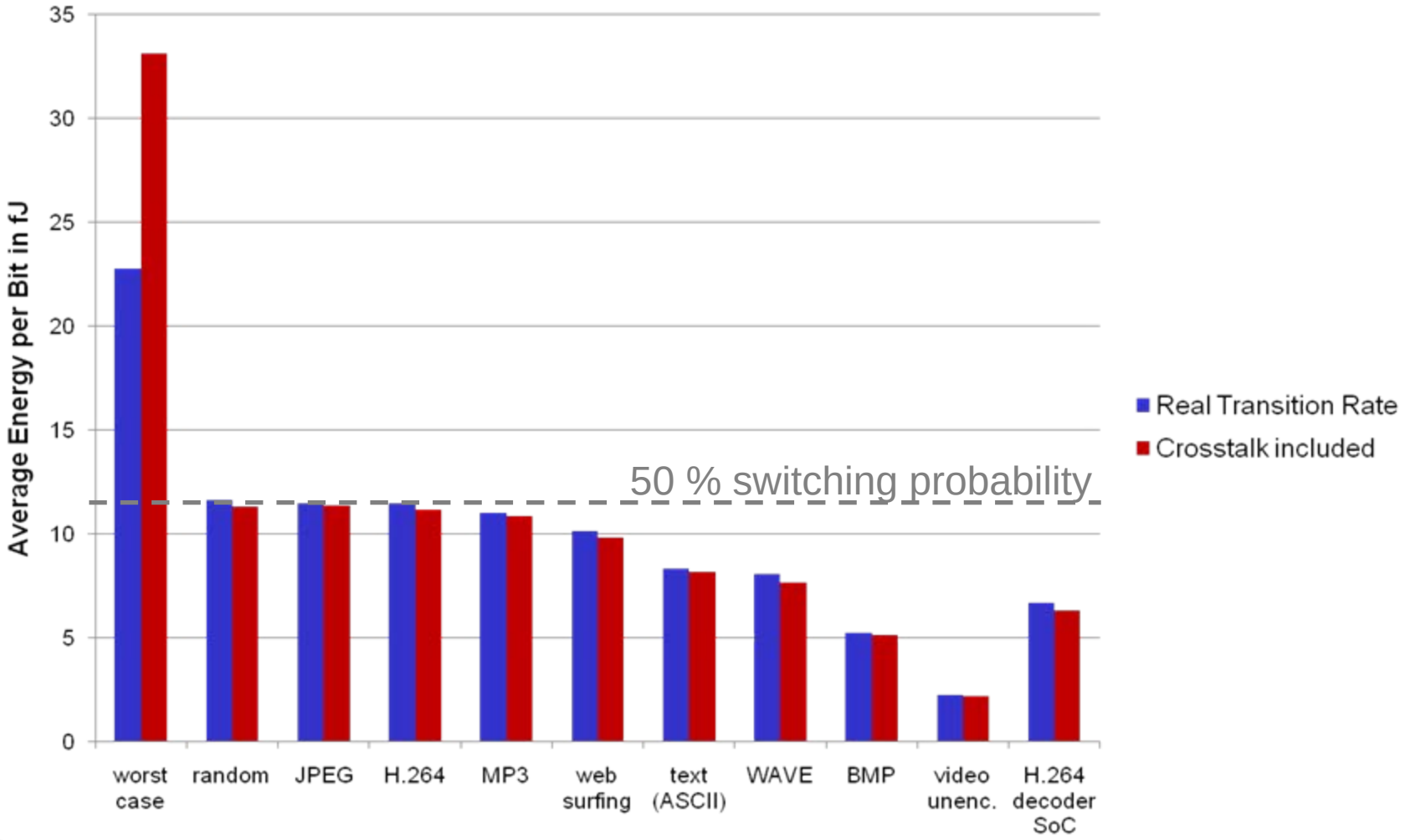
- Comparison of three estimation techniques
  - Set 50% transition rate (relates to random, uniform)
  - Measure the actual transition rate of real data
  - Actual transition rate and add crosstalk effects (DSM Bus Model)

# Results

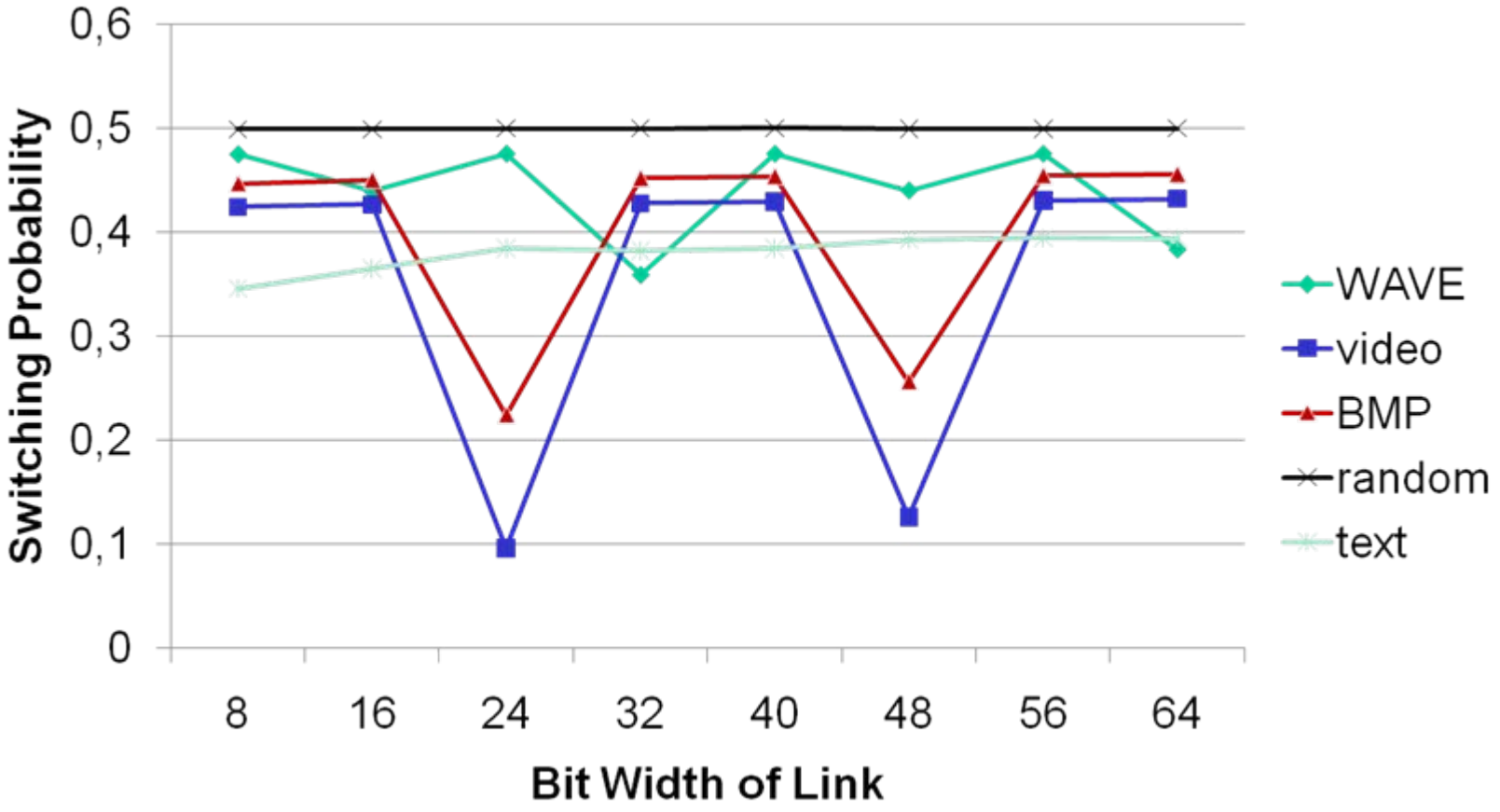
- Estimation examples:
  - Energy consumption in relation to real transition rates including crosstalk effects

| Data | Transition rate | 50% activity |
|---|---|---|
| Worst Case | -31% | -65% |
| Random | +2% | +3% |
| JPEG | +1% | +2% |
| BMP | +2% | +127% |
| Unenc. Video | +2% | +433% |
| Average Traffic in H264 Decoder | +6% | +85% |

# Results


Average Energy per Bit in fJ
35
30
25
20
15
10
5
0
50 % switching probability
worst case
random
JPEG
H.264
MP3
web surfing
text (ASCII)
WAVE
BMP
video unenc.
H.264 decoder SoC
Real Transition Rate
Crosstalk included

# Results


0,6
0,5
0,4
0,3
0,2
0,1
0
Switching Probability
8
16
24
32
40
48
56
64
Bit Width of Link
WAVE
video
BMP
random
text

# Conclusion

- Knowledge of data or at least its statistics is very important for energy estimation
- Positive and negative crosstalk effects compensate each other -> no crucial influence
- Dynamic energy consumption on links depends highly on matching between signal and link width

# Outlook

- Include the link energy estimation technique in high level architectural simulations
- Add energy model of routers to complete NoC-Model
- Add Transition and Crosstalk Avoidance Codes into simulation environment