# What happens on an MPSoC stays on an MPSoC – unfortunately!

Evolving Debugging to Diagnosis

Philipp Wagner*, Lin Li‡, Thomas Wild*, Albrecht Mayer‡, Andreas Herkersdorf*
* Technische Universität München, ‡ Infineon Technologies AG

Institute for Integrated Systems
Technische Universität München

MPSoC Forum, Ventura Beach, CA
2015-07-14

## Why Improve Debugging?

In the US, every day **5 out of 12** engineers spend their day finding and fixing bugs.

That's **1 million engineers**.

[Jones, 2011]

## Why Improve Debugging?

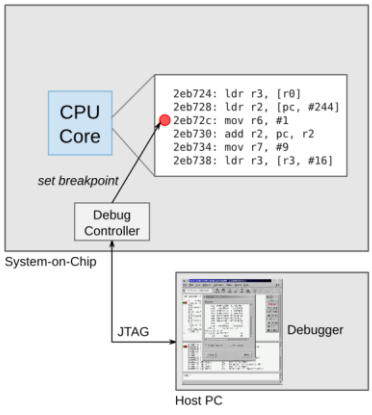
# $ 312,000,000,000

cost of software bugs to the global economy, per year

[Britton et al, 2013]



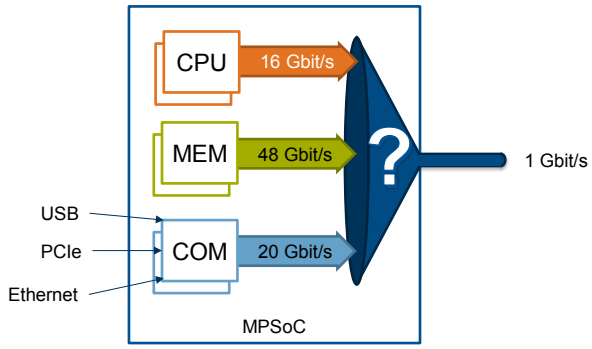
## Run-Control Debugging




probe effect!

## Trace-Based Debugging

The Situation Today: Drowning in Data

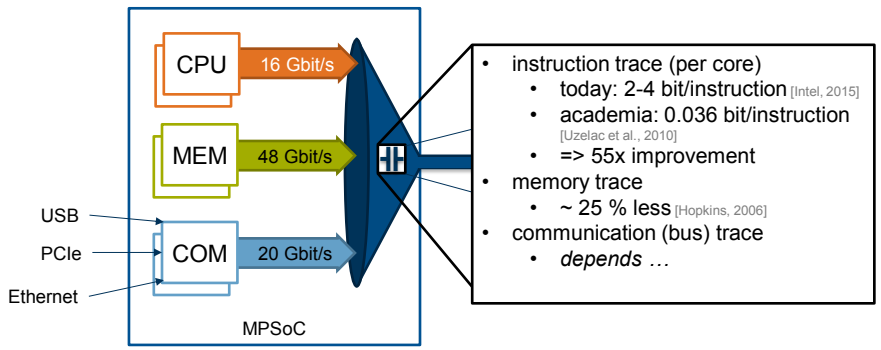



Example system: 4 CPU cores @ 2 GHz, 64 Gbit/s memory bandwidth, 20 Gbit/s I/O bandwidth
Instruction trace compressed to 2 bit/cycle/core, memory trace compressed to 0.75 x memory bandwidth, uncompressed communication (bus) trace



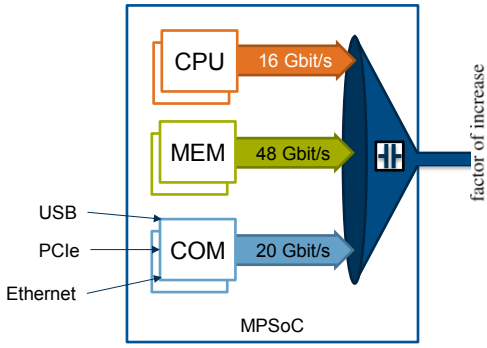
## Trace-Based Debugging

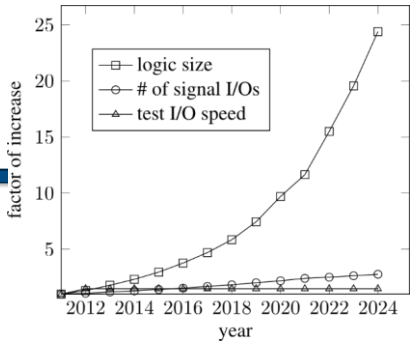
Situation Tomorrow: Better Compression?



## Trace-Based Debugging

Situation Tomorrow: Better Off-Chip Interfaces?




Data from ITRS roadmap, 2013 edition.



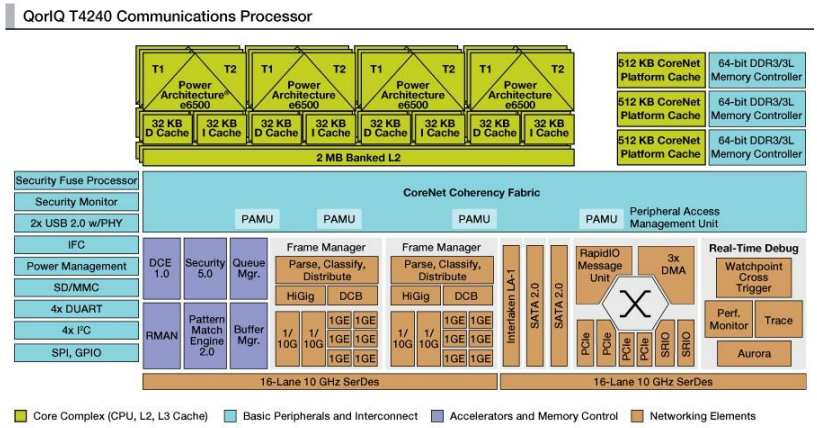
## Complex Software …

**Want to display web content?**

"The average number of **changes accepted into the kernel per hour is 7.71**, which translates to 185 changes every day and nearly 1,300 per week."
[Linux, 2015]


**6.9 code changes per hour** [Mozilla, 2015]

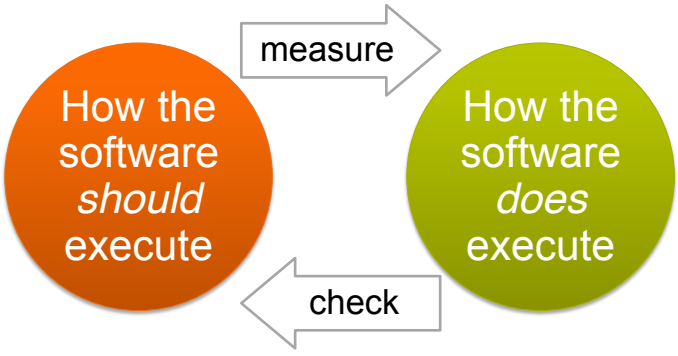
## Complex Software … Meets Complex Hardware




Freescale QorIQ T4240 block diagram
http://cache.freescale.com/files/graphic/block_diagram/T4240_BD_IMG.jpg



## Software Debugging from 10,000 ft



## Knowledge-Based On-Chip Diagnosis

How the software *should* execute

**Knowledge-Based Diagnosis**

Data + Expert Knowledge = Information

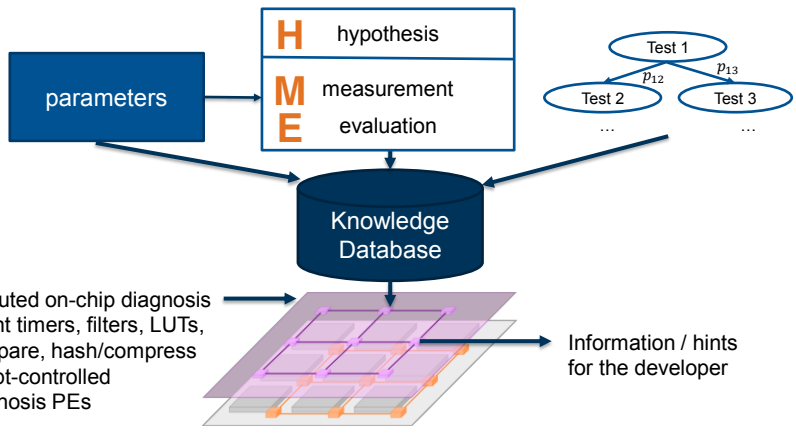
How the software *does* execute

**On-Chip Diagnosis**

$\rho_{information} > \rho_{data}$



## Knowledge-Based Diagnosis



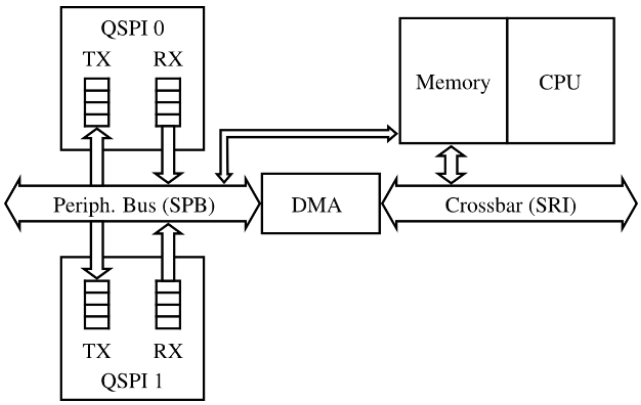
## A Code Issue

```
while (1) {
  // wait until at least one QSPI module is ready
  s0 = IfxQspi_SpiMaster_getStatus(&spiChannel);
  s1 = IfxQspi_SpiMaster_getStatus(&spiChannel2);
  while (s0 == SpiIf_Status_busy ||
    s1 == SpiIf_Status_busy);
  }
  initiate_next_transmission()
}
```

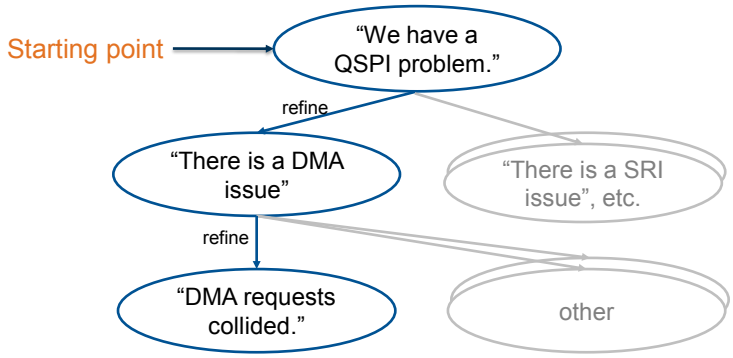
program hangs here



## A Code Issue … Involving the Hardware

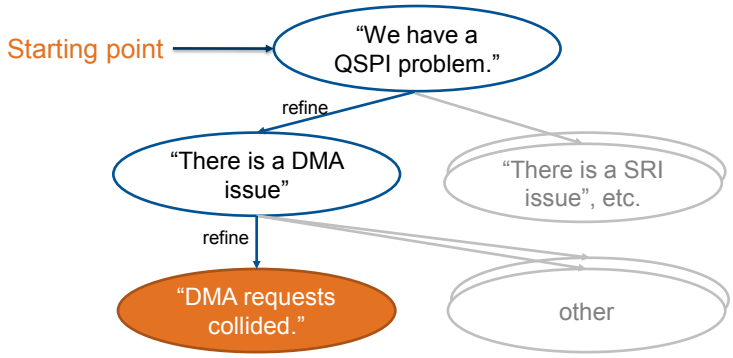


## Case Study: Tree of Tests

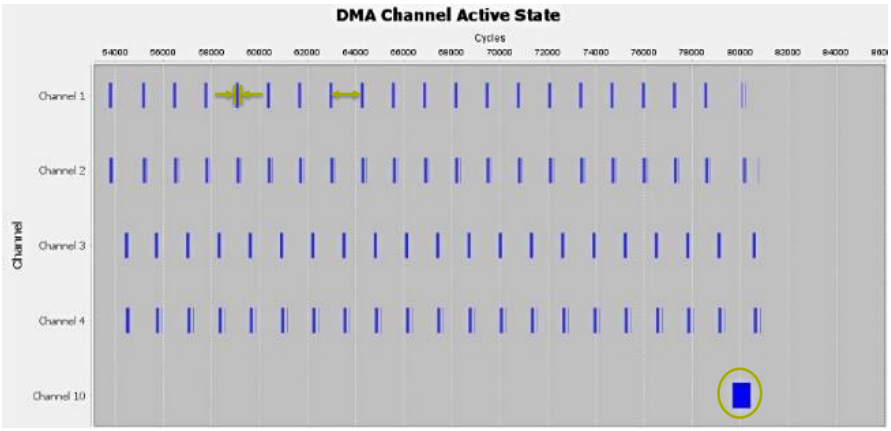





## Case Study: Tree of Tests

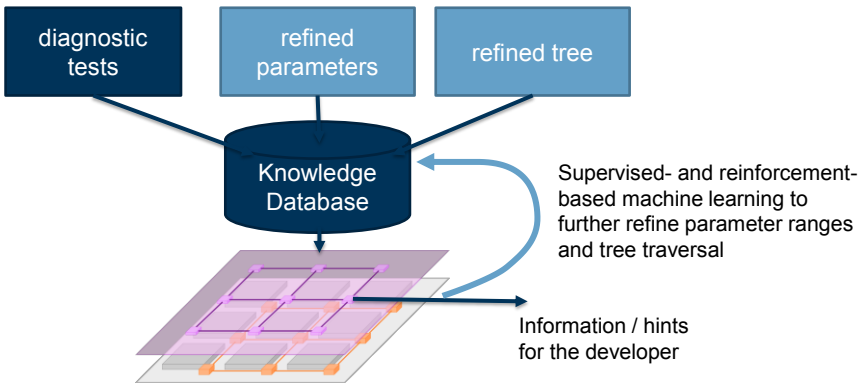


## Did DMA Requests Collide? A Search Problem.






## Refining Knowledge-Based Diagnosis



## Problems We Cannot Solve

- Issues must be reproducible or recurring
- Hard-to-find bugs will remain
- Detection is only the first step: fixing bugs remains the developers job


French Finds on flickr, CC-BY-NC



## Conclusion

- Understanding MPSoC behavior is difficult
  - complex hardware & software
  - cannot hide behind abstractions
- Software execution generates too much data …
  - to be transferred off-chip
  - to be consumed and understood by humans

- **We envision a smart (expert knowledge and machine learning driven) on-chip diagnosis solution to guide the SW developer to critical areas!**

# Your Questions?

**Contact**
Andreas Herkersdorf <herkersdorf@tum.de>
Institute for Integrated Systems, TUM, Munich, Germany

**Further reading**
Ph. Wagner, L. Li, T. Wild, A. Mayer, and A. Herkersdorf, "Knowledge-Based On-Chip Diagnosis for Multi-Core Systems-on-Chip," edaWorkshop 15, Dresden, Germany, 2015



## References


- **[Britton et al, 2013]** T. Britton, L. Jeng, G. Carver, P. Cheak, und T. Katzenellenbogen, „Reversible debugging software", Technical report, University of Cambridge, Judge Business School, 2013.
- **[Jones et al, 2011]** C. Jones, J. Subramanyam, und O. Bonsignour, *The Economics of Software Quality*. Upper Saddle River, NJ: Prentice Hall, 2011.
- **[Intel, 2015]** Intel® Trace Hub Developer's Manual. Revision 1.0., 2015.
- **[Hopkins, 2006]** Hopkins, Andrew B. T., und Klaus D. McDonald-Maier. „Debug support strategy for systems-on-chips with multiple processor cores". IEEE Transactions on Computers 55, Nr. 2 (Februar 2006): 174–84. doi:10.1109/TC.2006.22.
- **[Uzelac et al., 2010]** Uzelac, Vladimir, Aleksandar Milenković, Martin Burtscher, und Milena Milenković. „Real-time unobtrusive program execution trace compression using branch predictor events". In Proceedings of the 2010 International Conference on Compilers, Architectures and Synthesis for Embedded Systems, 97–106. CASES '10. New York, NY, USA: ACM, 2010. doi:10.1145/1878921.1878938.
- **[Linux, 2015]** J. Corbet, G. Kroah-Hartman, und A. McPherson, „Linux Kernel Development: How Fast is it Going, Who is Doing It, What Are They Doing and Who is Sponsoring the Work". Feb-2015.
- **[Mozilla, 2015]** K. Moir, "Mozilla pushes - April 2015", Releng of the Nerds, 01-May-2015. Online: http://relengofthenerds.blogspot.de/2015/05/mozilla-pushes-april-2015.html