Trace Debugging in Academics – the Future of Multicore Debugging?

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http://www.lis.ei.tum.de

Well-known roads

http://en.wikipedia.org/wiki/File:Hume_Freeway_Craigieburn_Bypass.jpg
Wikipedia user Melburnian, CC-BY-SA

Road Signs: Where are we going?

And a Glimpse Beyond?

http://www.flickr.com/photos/dougtone/6172050448
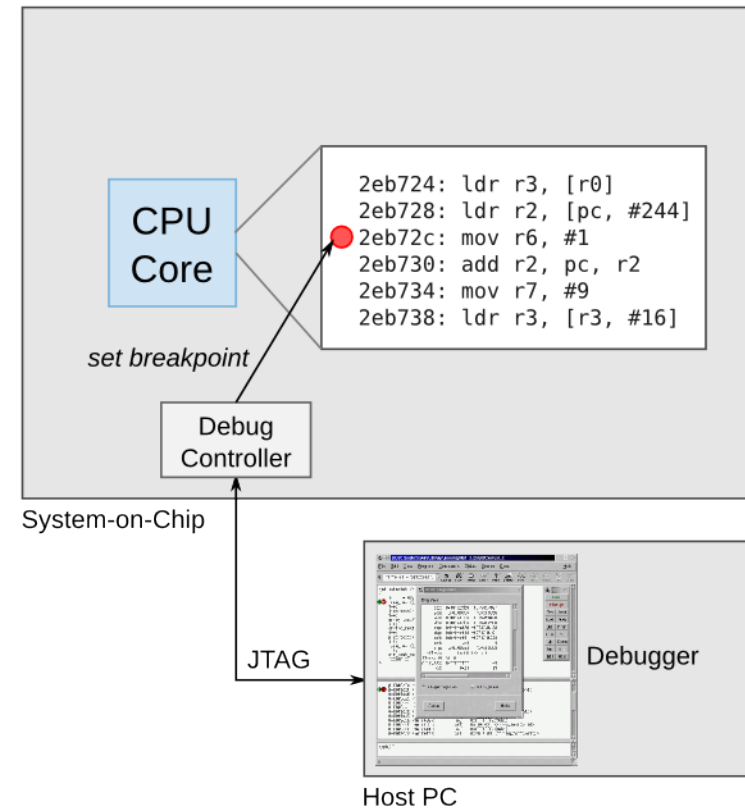flickr user "dougtone", CC-BY-SA (edited)

The Road to Multicore Debug – Overview

- How we're debugging now
- Tracing – the new way of Multicore Debugging
  - How we're doing it now
  - How we might do it in the future

Proven and Tested:
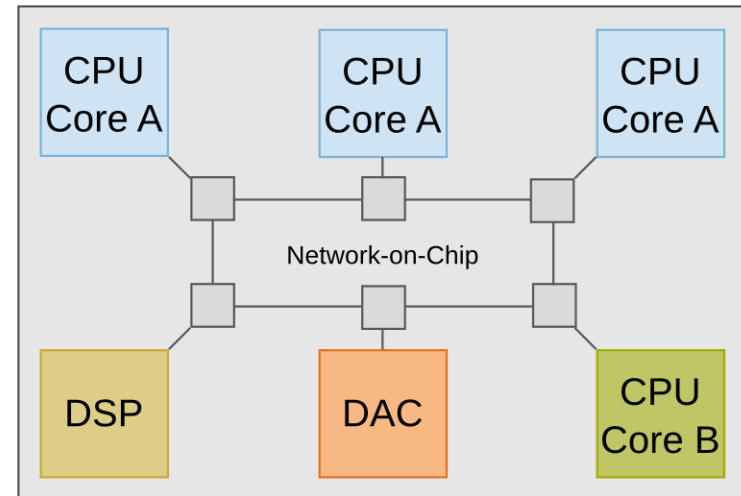
The way we debug today.

Run-Control Debug

- It's easy

- It's well-known

- It works great
  - for programs that have no/little concurrent parts

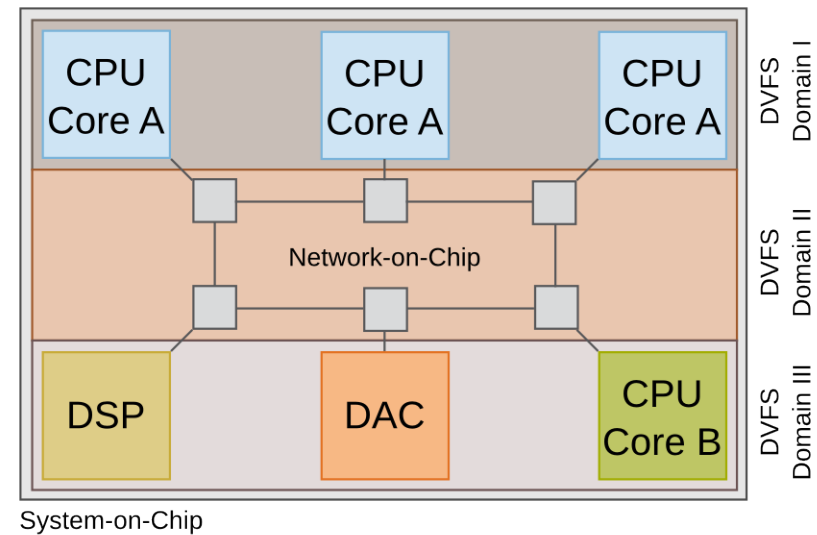- Today that's the majority of software!

Run-Control Debug

- What to do with
  - complex, heterogeneous systems?
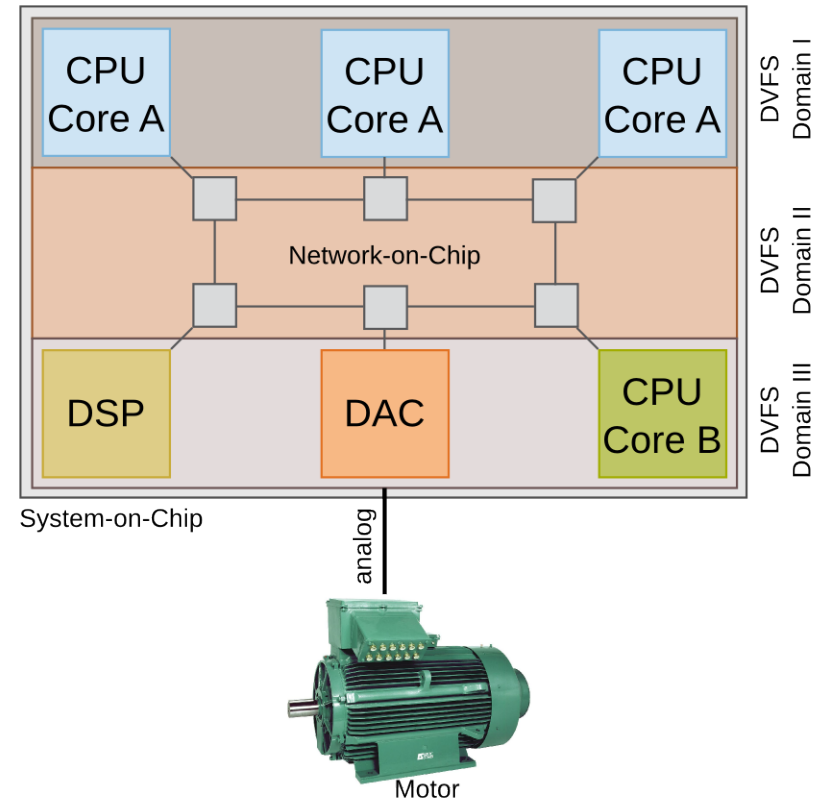 - concurrency problems?

System-on-Chip

Run-Control Debug

- What to do with
  - complex, heterogeneous systems?
  - concurrency problems?
- Different clock domains

System-on-Chip

Run-Control Debug

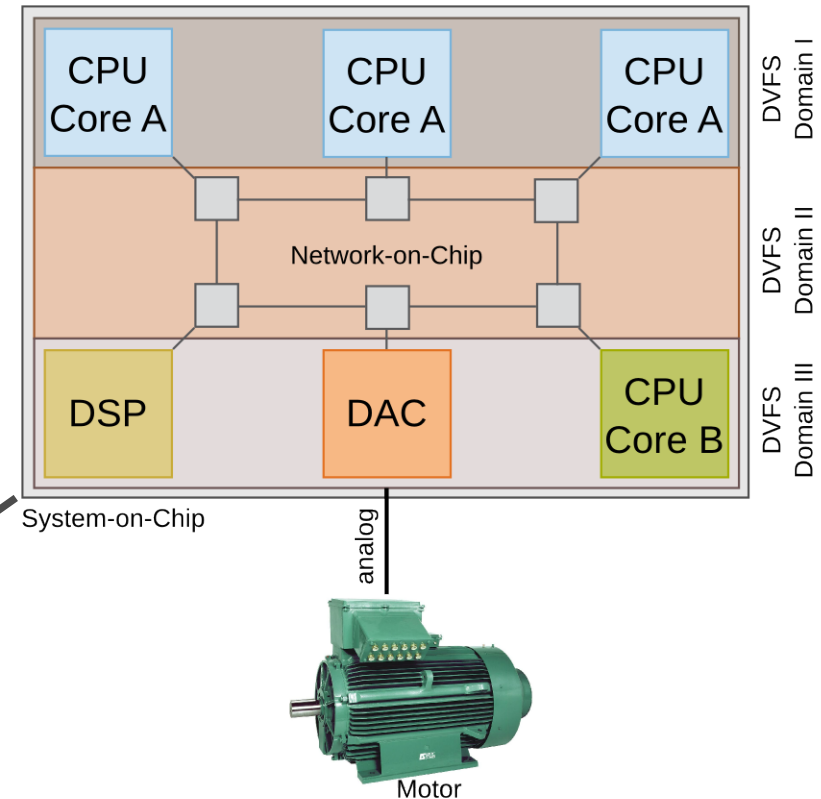- What to do with
  - complex, heterogeneous systems?
  - concurrency problems?
- Different clock domains
- Real-time?

Motor:
http://commons.wikimedia.org/wiki/File:Ac-elektromotor-robuster-asynchronmotor.jpg
User "Egzon123" on Wikipedia, CC-BY-SA

Run-Control Debug

- What to do with
  - complex, heterogeneous systems?
  - concurrency problems?
- Different clock domains
- Real-time?
- Unattended debug?

Wind turbine:
http://images.cdn.fotopedia.com/flickr-185488411-original.jpg
User "phault" on Flickr, CC-BY

A Road Sign: Tracing

- Can find concurrency bugs
- Can work in heterogeneous environments
- Can be non-intrusive
- Can be unattended

http://www.flickr.com/photos/countylemonade/5321535677
User "Garrett" on flickr, CC-BY (edited)

Tracing can solve the problems of run-control debugging!

Road Bumps

Data Trace for a DDR3 Memory [1]

DDR3-1333 Peak Data Rate: ~ 10 GByte/s

Compression for an average memory trace:
~ 50 % reduction
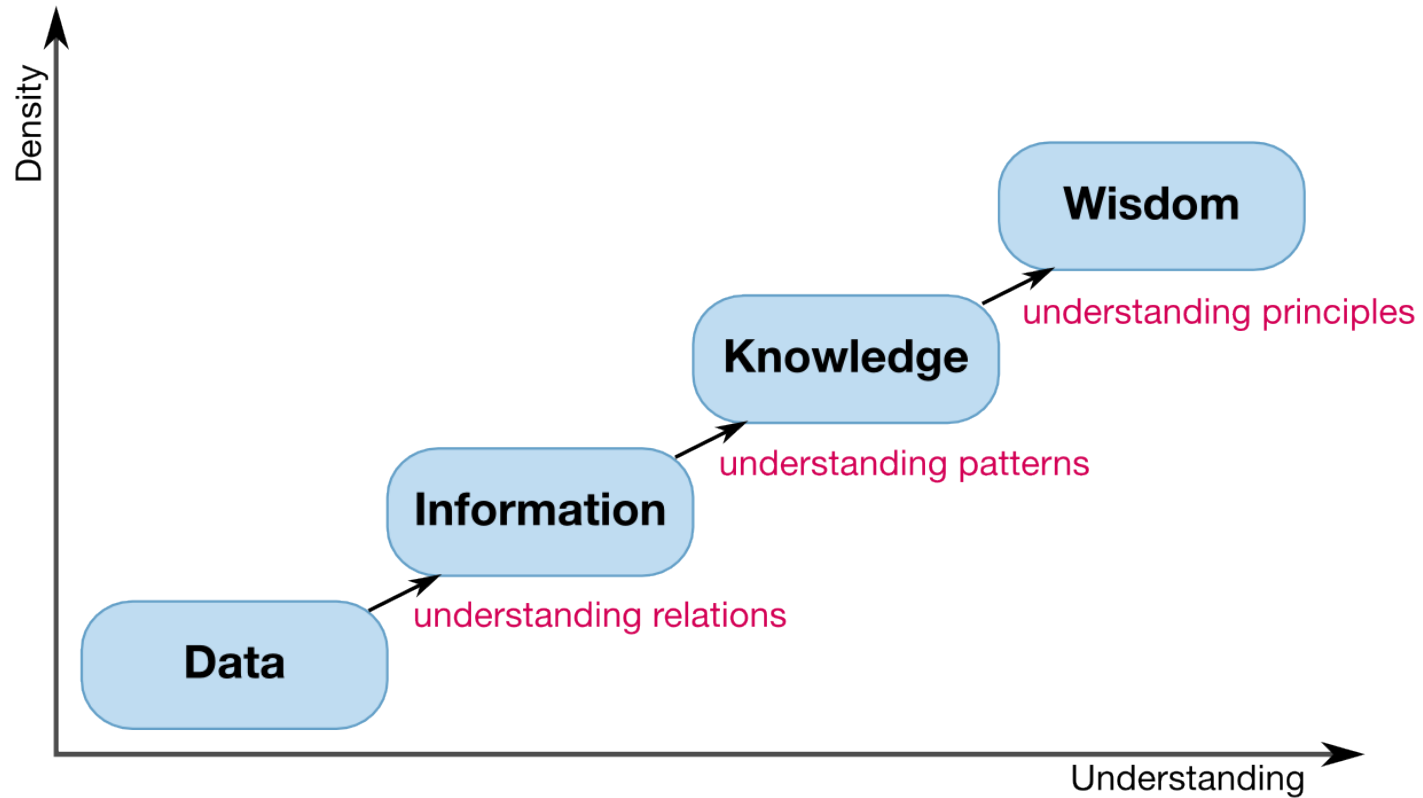
NEXUS 5001 Trace Port [2]

Freescale MPC5777M

4 lanes of 1 GBit/s Xilinx Aurora trace port

40 GBit/s data generation ⟷ **4 GBit/s off-chip**

[1] Data compression rate: Christian Morgenstern, "Collection and Compression of Memory Traces for Manycore System-On-Chip", Bachelor Thesis, 2013
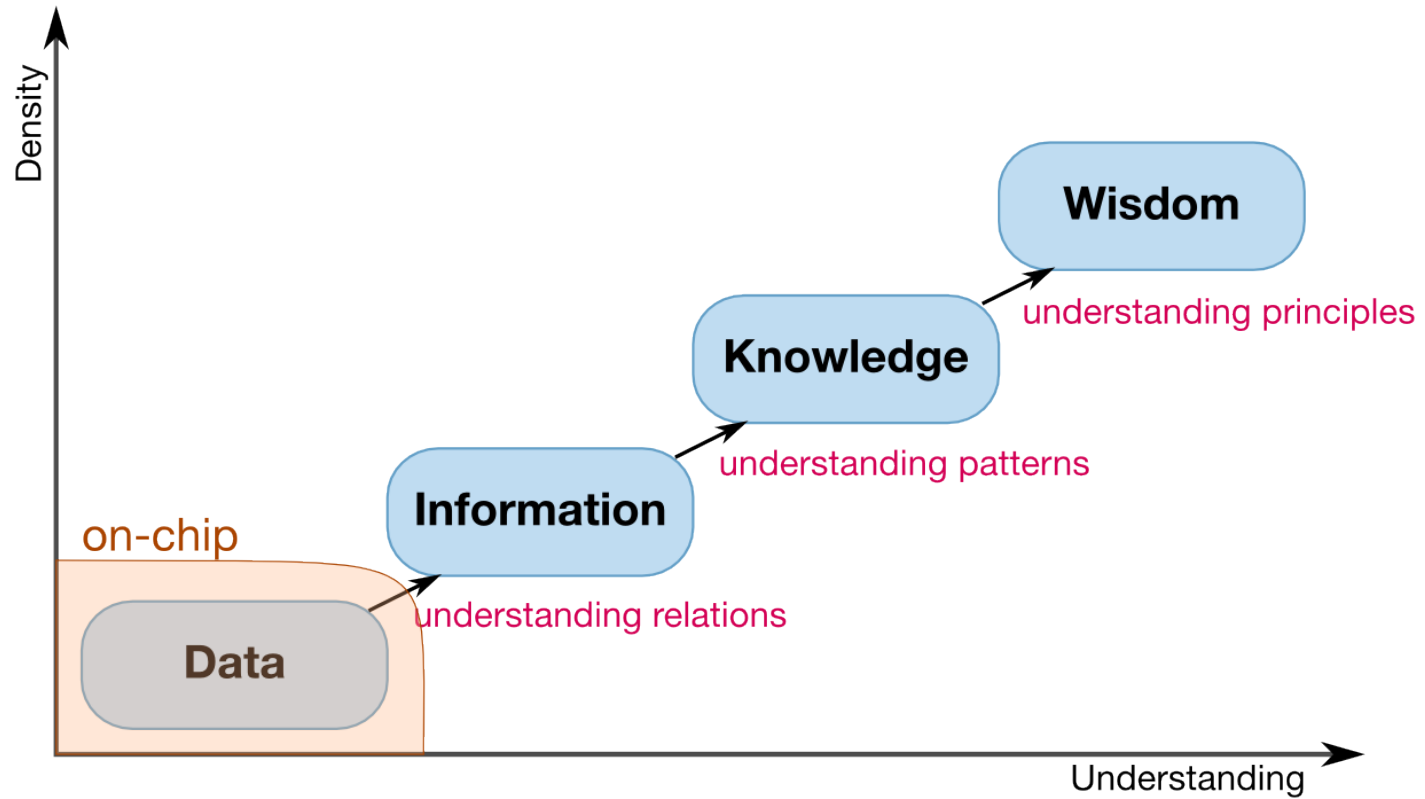
[2] Only on the emulation device, 4 lanes w/ 1.25 GBit/s data rate and 8b10b encoding. Ignoring all NEXUS 5001 message overhead.
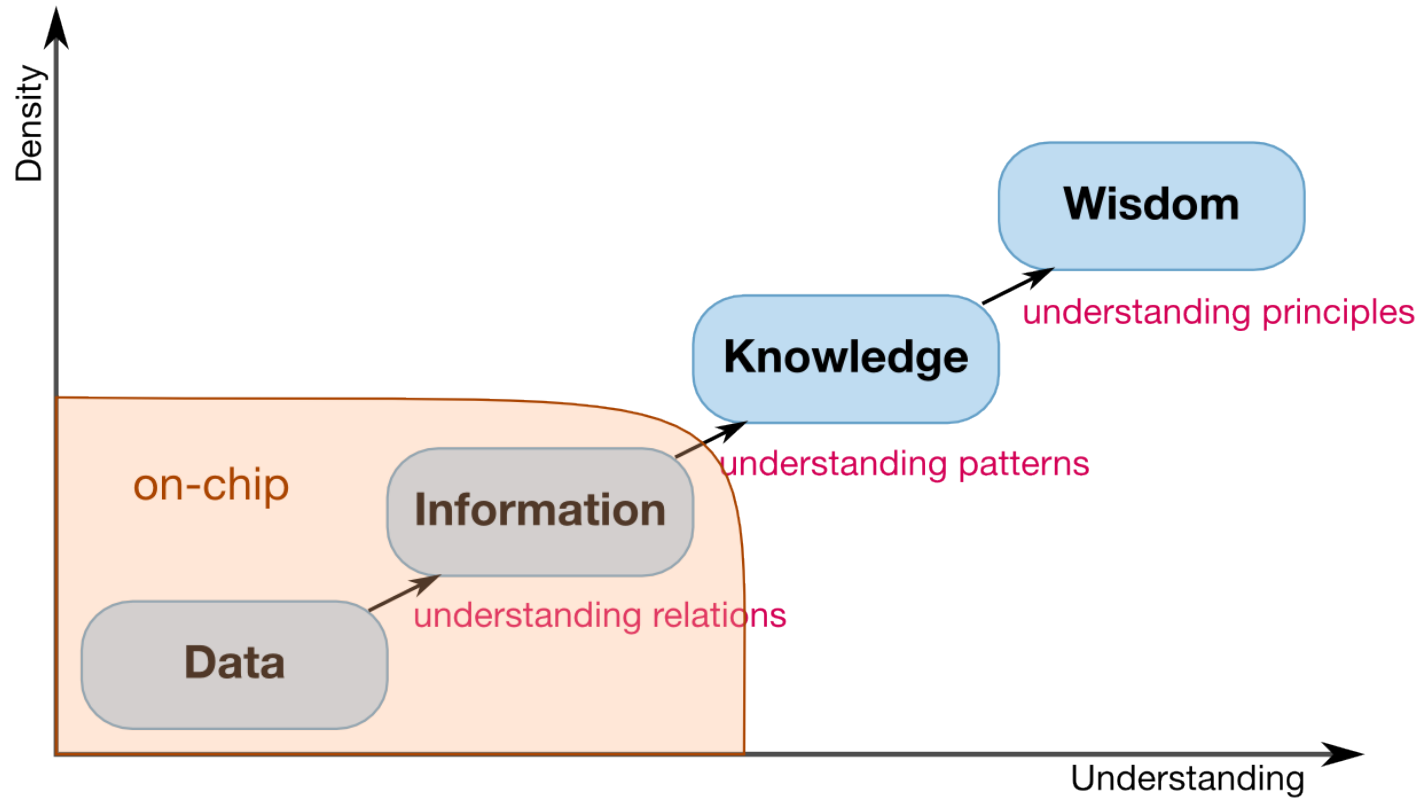
Think! On Chip.

DIKW Chain (Ackoff, 1989). This representation is inspired by Gene Bellinger, "Knowledge Management—Emerging Perspectives". http://www.systems-thinking.org/kmgmt/kmgmt.htm. 2004

Think! On Chip.

Think! On Chip.

Attach meaning to data on chip
Reduce amount of data to send off chip

From Data to Information: First Road Signs

- Information from the software developer
  - ARM CoreSight System Trace Macrocell (STM),
    NEXUS 5001-2008 Data Acquisition Messaging (DQM)
  - like `printf()`/`kprintf()` with hardware support
- Configurable trace collection
  - Infineon MCDS
- Recognizing known bugs
  - On-chip Data Race Detection [Wen et. al, 2012]

C.-N. Wen, S.-H. Chou, C.-C. Chen, and T.-F. Chen, "NUDA: A Non-Uniform Debugging Architecture and Nonintrusive Race Detection for Many-Core Systems," *IEEE Trans. Comput.*, vol. 61, no. 2, pp. 199 – 212, Feb. 2012.

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From Data to Information: Take it a Step Further

1. Give the developer a way to express the meaning of the data
2. Add on-chip hardware to actually extract information out of data

Express the Meaning of Data

```
# increment a drop counter for every
# location we drop a packet at
probe kernel.trace("kfree_skb") {
  locations[$location] <<< 1
}


# Every 5 seconds report our drop locations
probe timer.sec(5) {
  printf("\n")
  foreach (l in locations-) {
    printf("%d packets dropped at %s\n",
          @count(locations[l]), symname(l))
  }
  delete locations
}
```

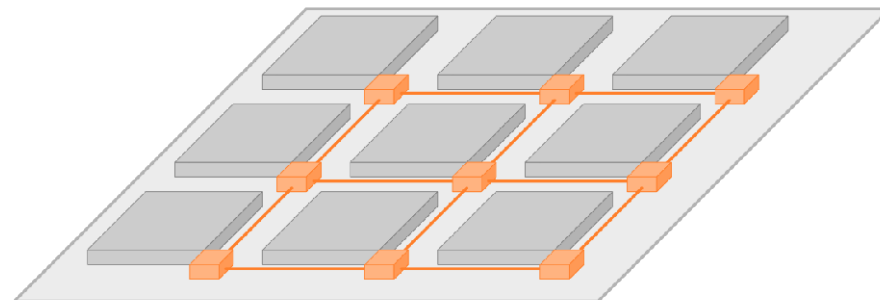**Data** point: Linux kernel function `kfree_skb()` is called

Information: dropped TCP packets

```
#> stap dropwatch.stp
3 packets dropped at 0xffffffff81495cfb

9 packets dropped at 0xffffffff81495cfb
1 packets dropped at 0xffffffff8154da4c

4 packets dropped at 0xffffffff81495cfb
2 packets dropped at 0xffffffff814f2100
```

SystemTap example from https://sourceware.org/systemtap/SystemTap_Beginners_Guide/useful-systemtap-scripts.html
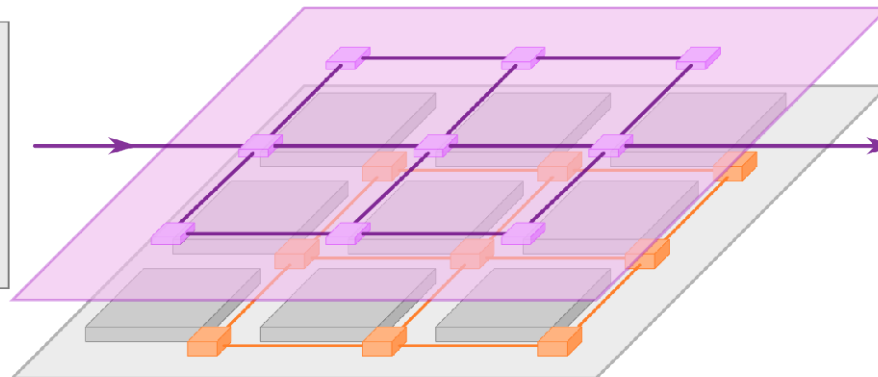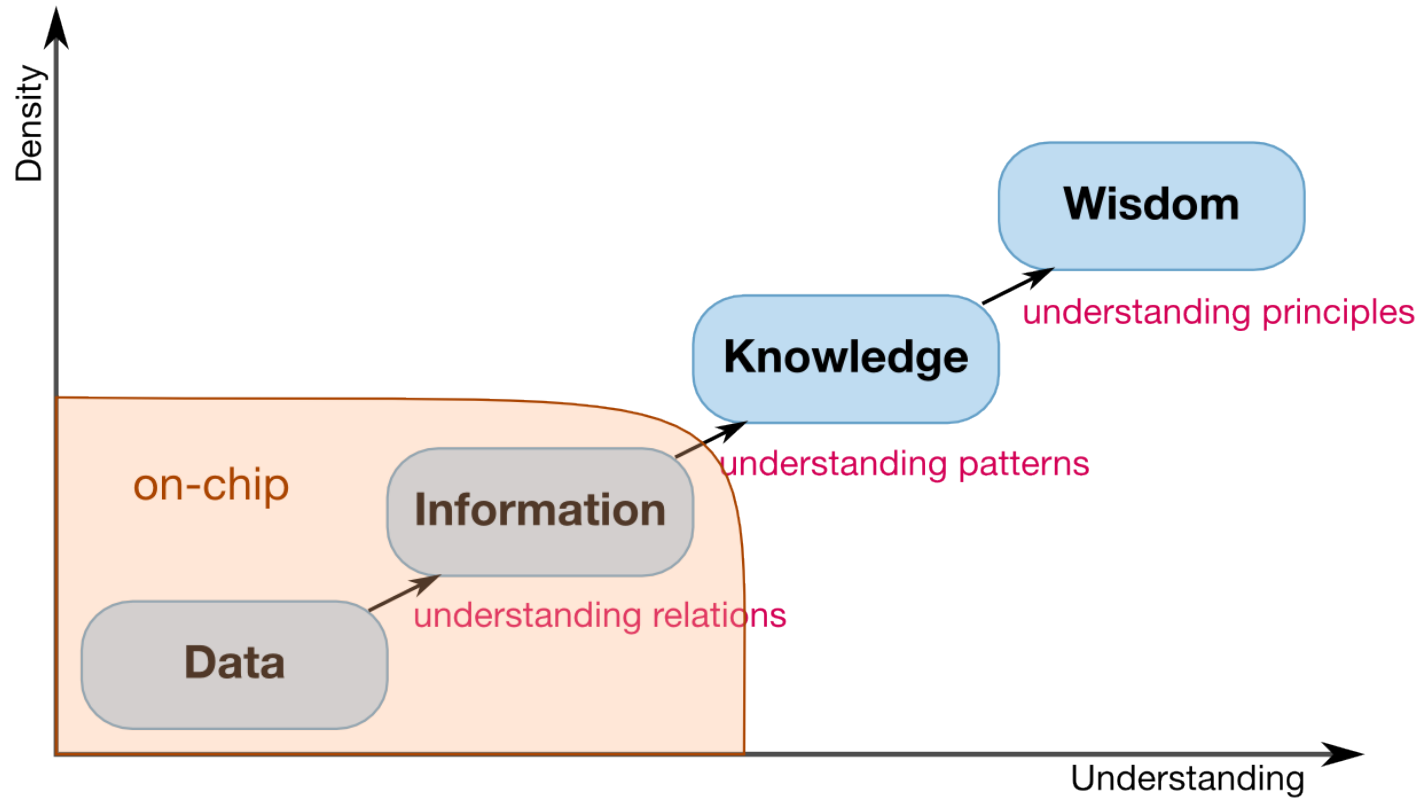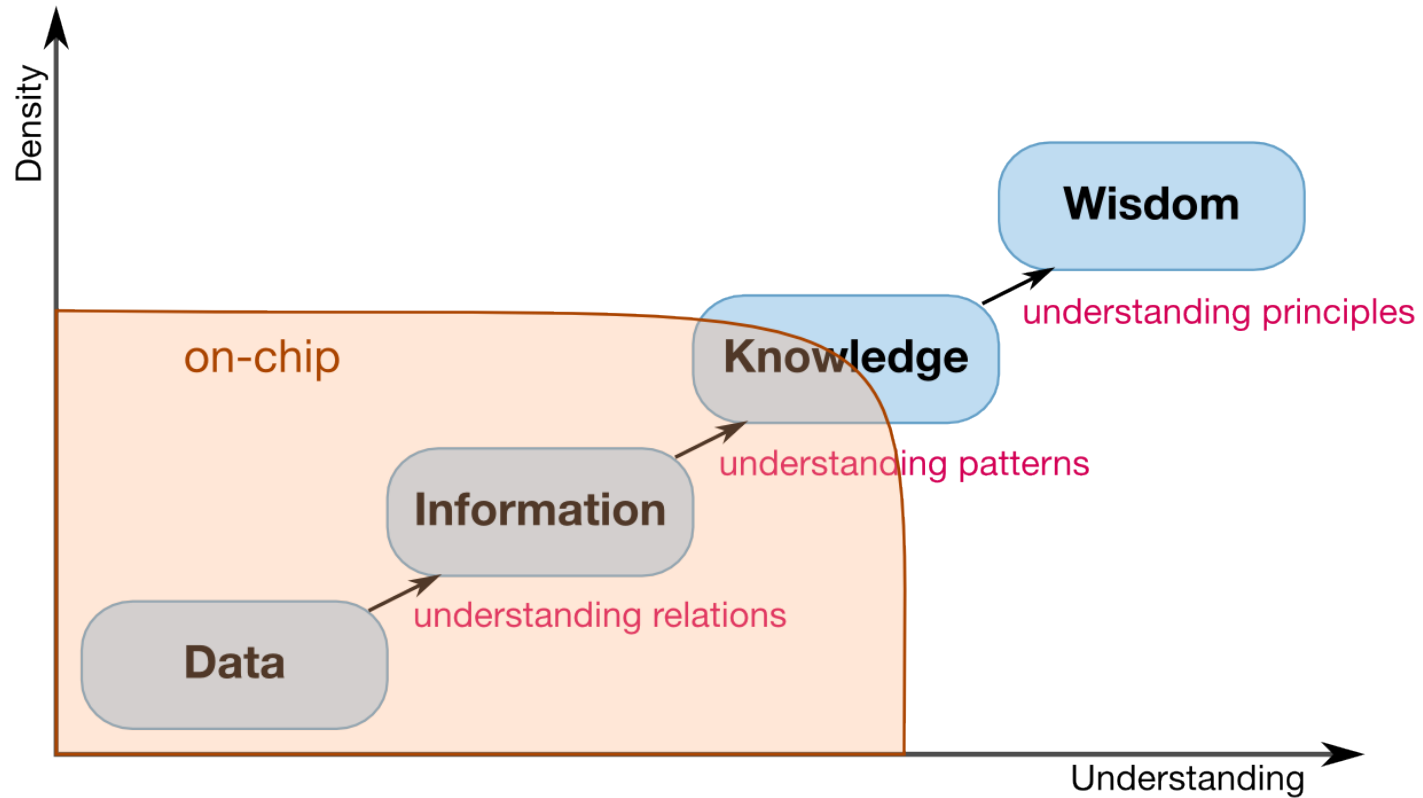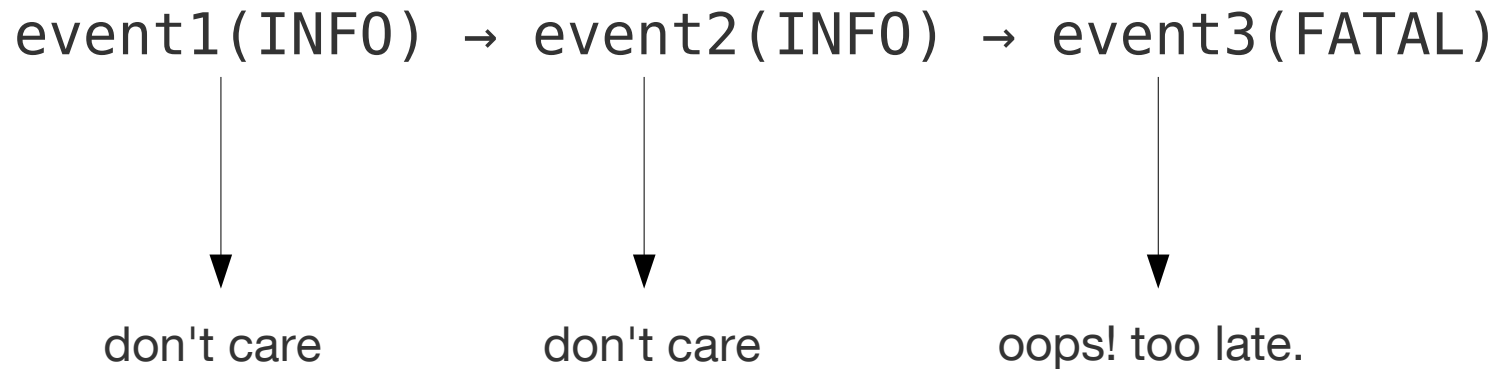
Now put it in hardware

Now put it in hardware

Think! On Chip.

Think! On Chip.

Find patterns.
From information to knowledge?

From Information to Knowledge

```
event1(INFO) → event2(INFO) → event3(FATAL)
```

don't care   don't care   oops! too late.

↻ this sequence repeats for a couple times

From Information to Knowledge

`event1(INFO) → event2(INFO) → event3(FATAL)`

Be careful. A fatal error might be coming up.   I saw it coming!

Pawlow's Dog: Reinforcement Learning

Can we bring machine learning into the chip?

Summary: The Road to Multicore Debug

- Less run-control debug, less full system tracing in the future
- Put debug intelligence inside the chip!
- Give meaning to data: "Debug Coprocessors"
- Find recurring patterns: Machine learning

Thank you for your attention.

Your Thoughts?

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