PF_ZIO: Using Network Frames to Convey I/O Data and Meta-Data

http://www.ohwr.org/projects/zio

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Channels, Csets, Devices

ZIO is concerned with I/O channels

- A channel is a single input or output wire

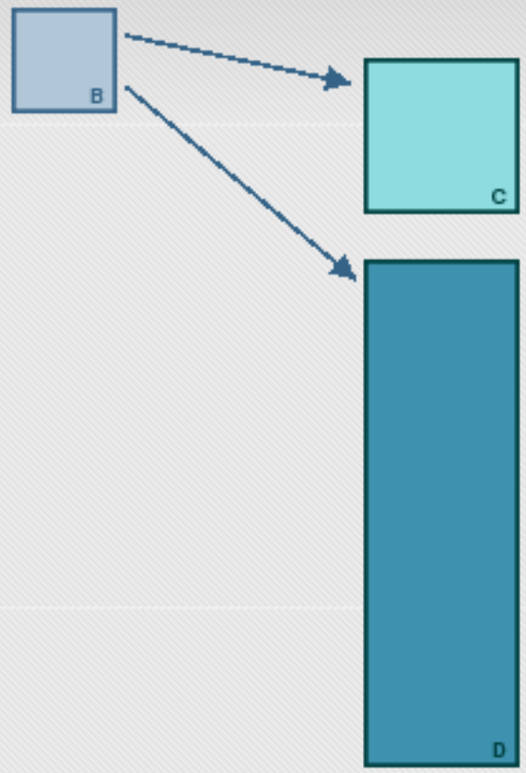
Channels are grouped in "channel sets"

- All channels in a cset share a trigger instance
- All channels in a cset use the same buffer type

Csets are grouped into devices

- A device is the register/unregister atomic entity
- Several devices of the same type can coexist

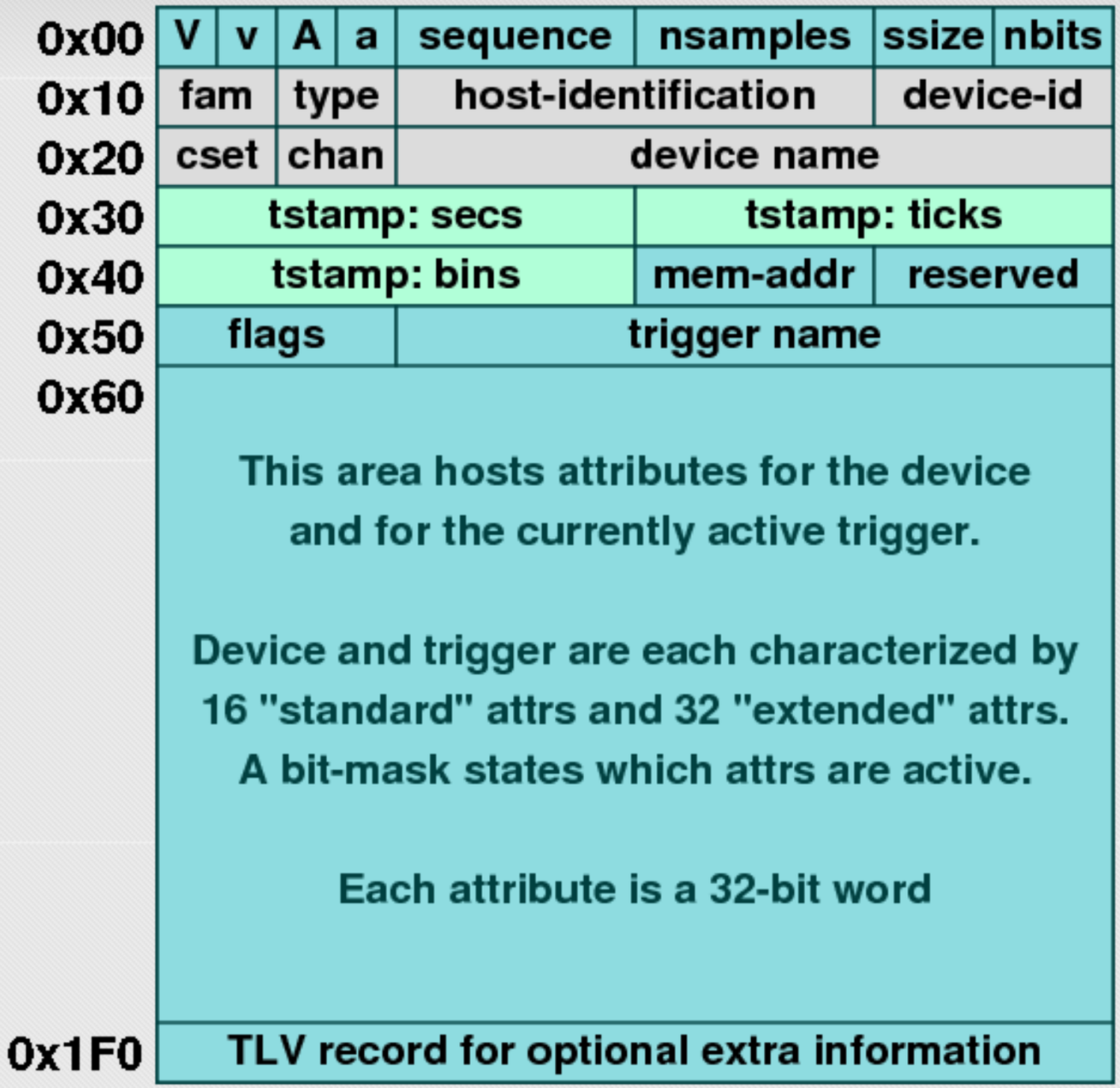
The Block



The atomic data item in ZIO is a block

- A block hosts data samples
- It also hosts meta-data (control information)
- Data within ZIO never travels without meta-data

The Control


0x00
V
v
A
a
sequence
nsamples
ssize
nbits
0x10
fam
type
host-identification
device-id
0x20
cset
chan
device name
0x30
tstamp: secs
tstamp: ticks
0x40
tstamp: bins
mem-addr
reserved
0x50
flags
trigger name
0x60
This area hosts attributes for the device
and for the currently active trigger.
Device and trigger are each characterized by
16 "standard" attrs and 32 "extended" attrs.
A bit-mask states which attrs are active.
Each attribute is a 32-bit word
0x1F0
TLV record for optional extra information

ZIO Device types

ZIO supports both input and output since inception

Our device types are "analog", "digital" or "time"

Input block:

- Data collected at a specific time or event

Output block:

- Data to be emitted at a specific time or event

"Time" channels:

- Digital pulses from/to laboratory equipment
- (No data is associated to a time channel)

The Hard Requirements behind ZIO

Hardware timestamps (better than 1ns precision)

Big data blocks (stripes of many samples)

Off-line creation/gathering of data blocks

High data rate

Easy monitoring of a diverse I/O environment

Support for several (many) boards of the same type

Design Choices behind ZIO

Sysfs-based configuration

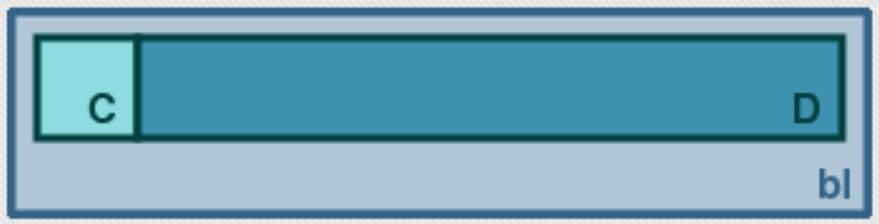
No ioctl(2) thank you

Centralized locks (drivers must ignore the issue)

Modular design (each object should be replaceable)

Documented and stable, with version control

All Items in a ZIO Framework



The block is overall blue

Control Cyan

Data Darker

Luser Lemon

Fops Forest

Socket Salmon

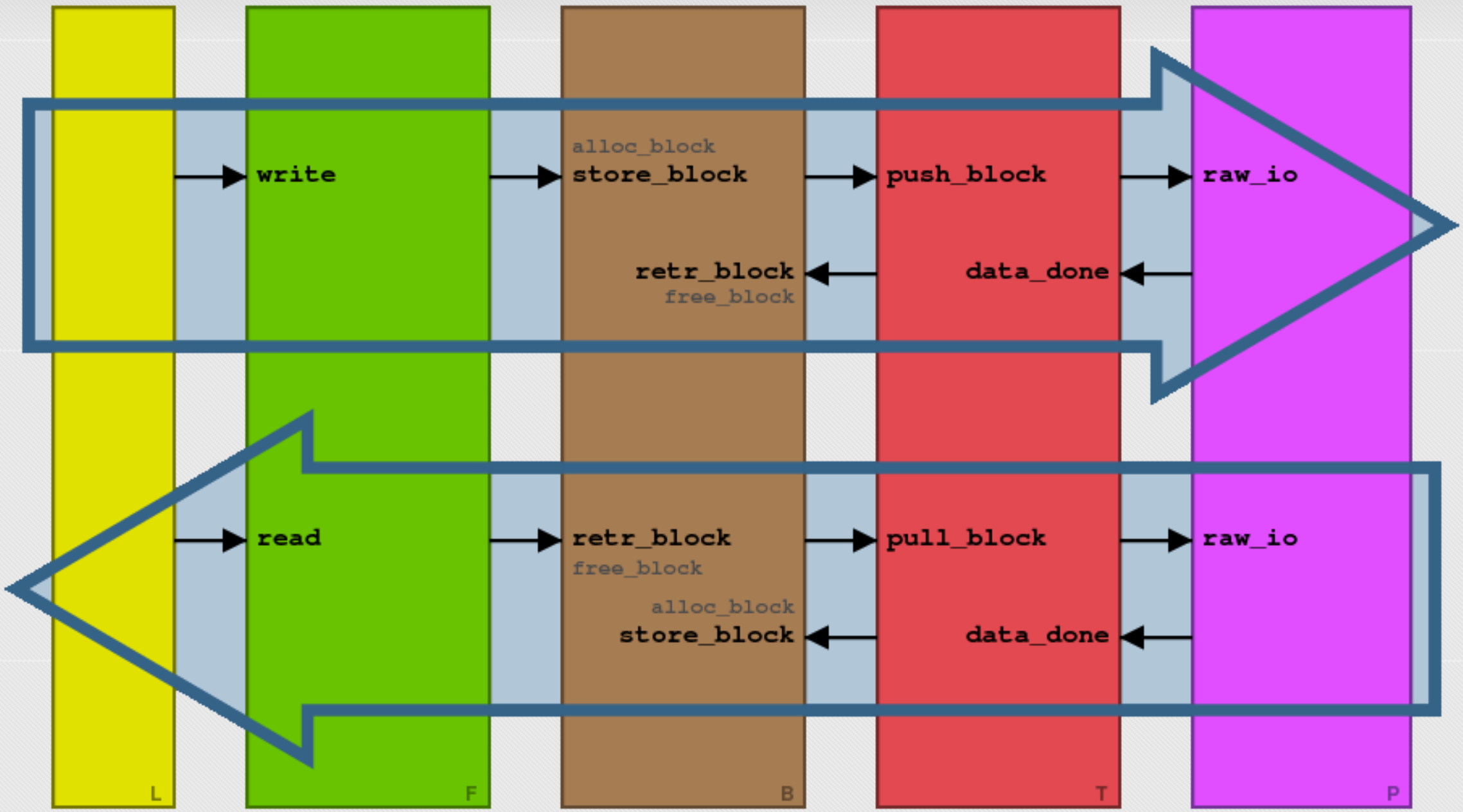
Buffer Brown

Trigger Tomato

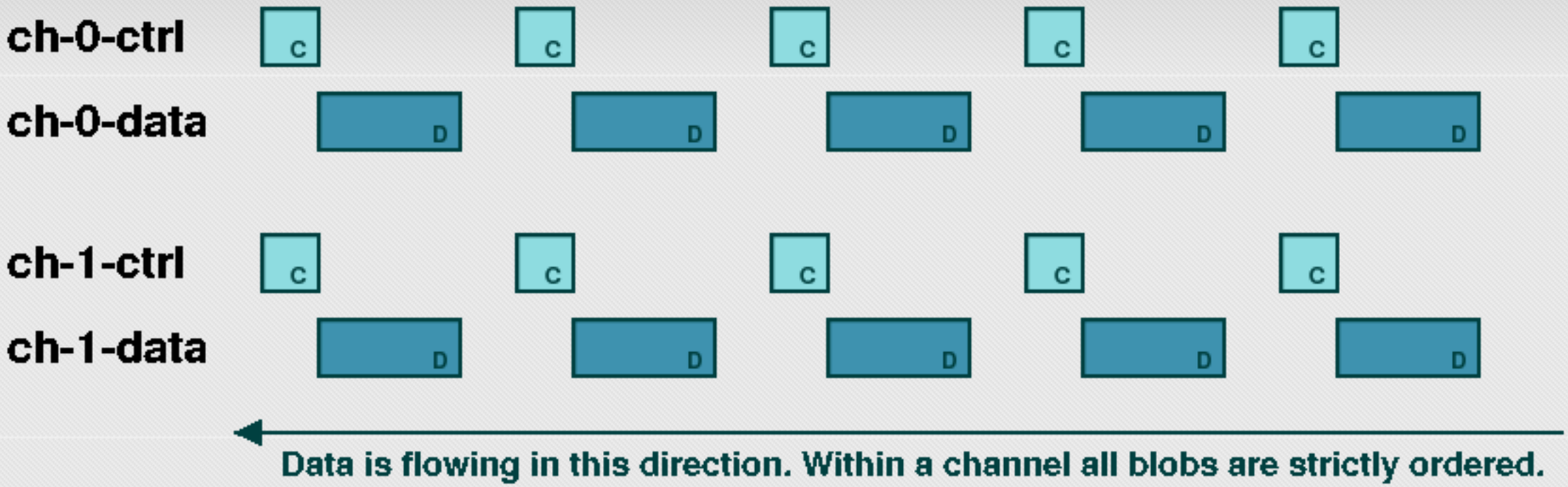
Periph. Purple

Network Neutral

ZIO pipeline, User to Hardware and Back



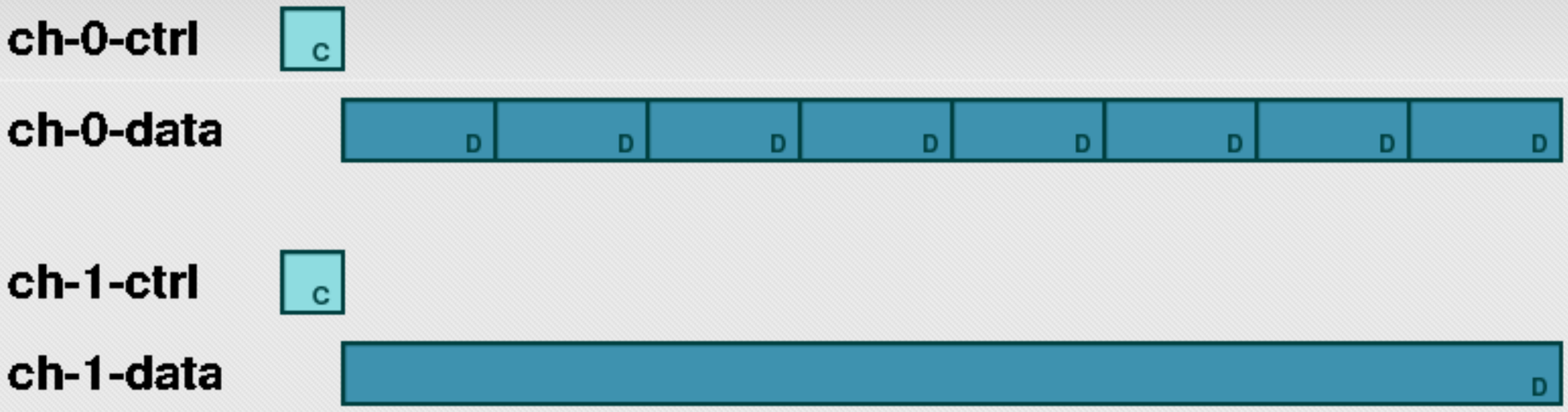
The Data Model Towards the User



Each channel is exported to user space as two char devices

- You can use blocking-read or poll on control, then read data
- Some users can choose to ignore control and just read data
- Other users can read control and ignore undesired data
- The "current" control block is exported, read-only, in sysfs
- Input and Output are completely symmetric

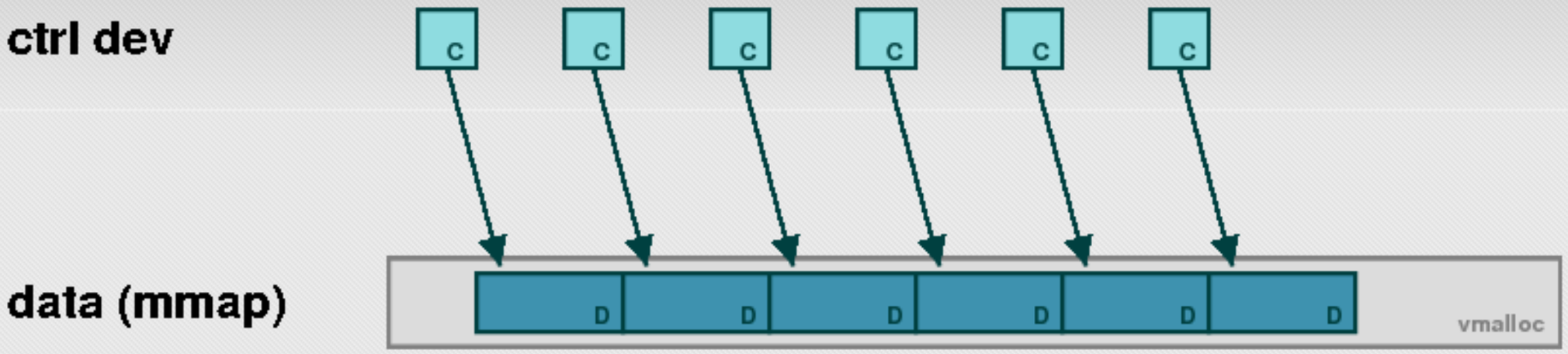
A Different Buffer Implementation



Users can change the buffer at runtime

- If you don't need the timestamp for each and every block...
- You can save buffering memory preserving the data model
- This is not the default, but can be chosen through sysfs

An mmap-capable Buffer Implementation



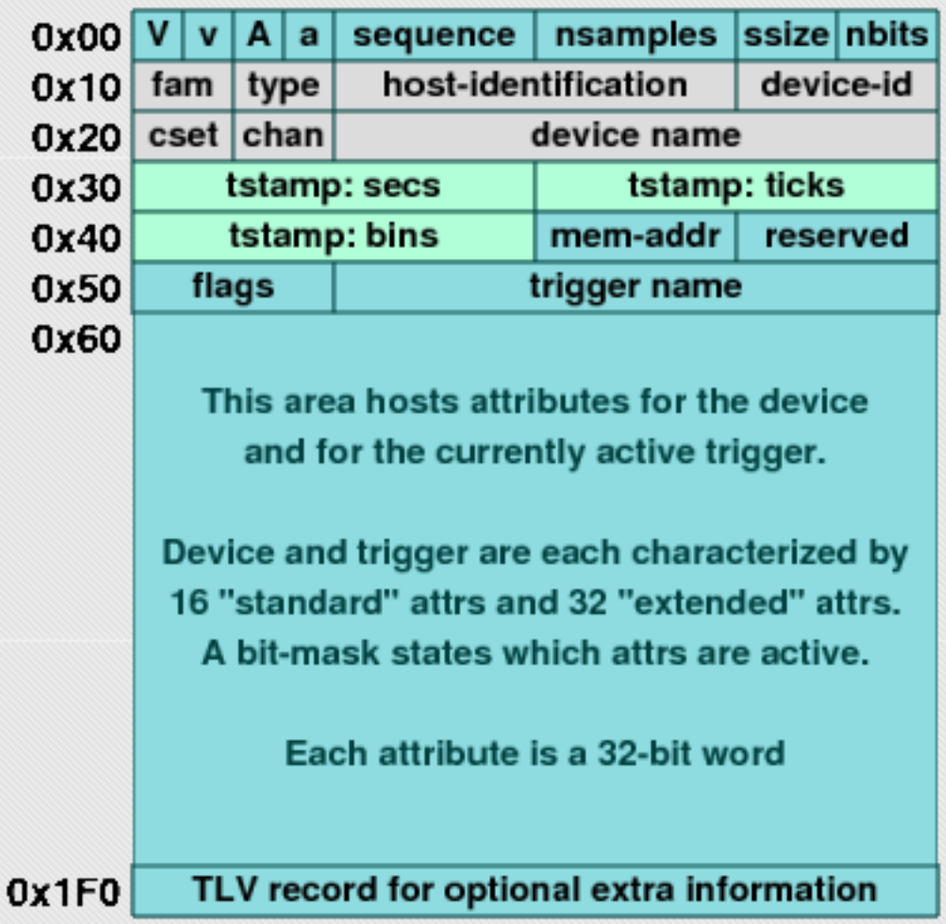
This is a buffer using vmalloc instead of kmalloc

- **The control includes an "mmap_offset" field**
- **You avoid one data copy with DMA-capable peripherals**

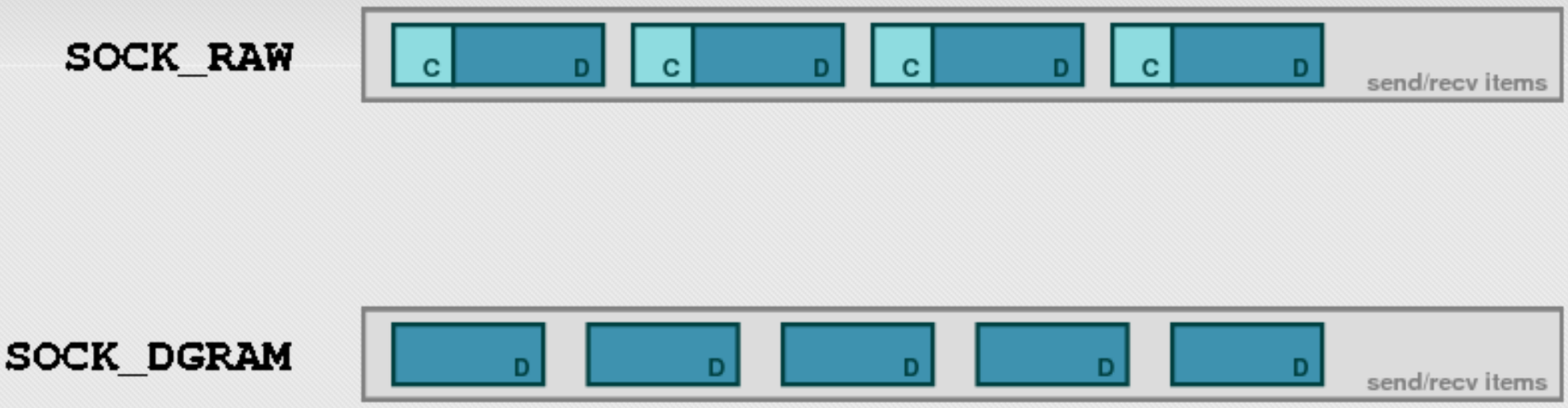
Defining PF_ZIO for I/O Blocks

The ZIO metadata+data model reminds network frames

- There are some advantages in socket programming
- So we chose to implement PF_ZIO as a socket family
- The control already includes an addr_zio structure...



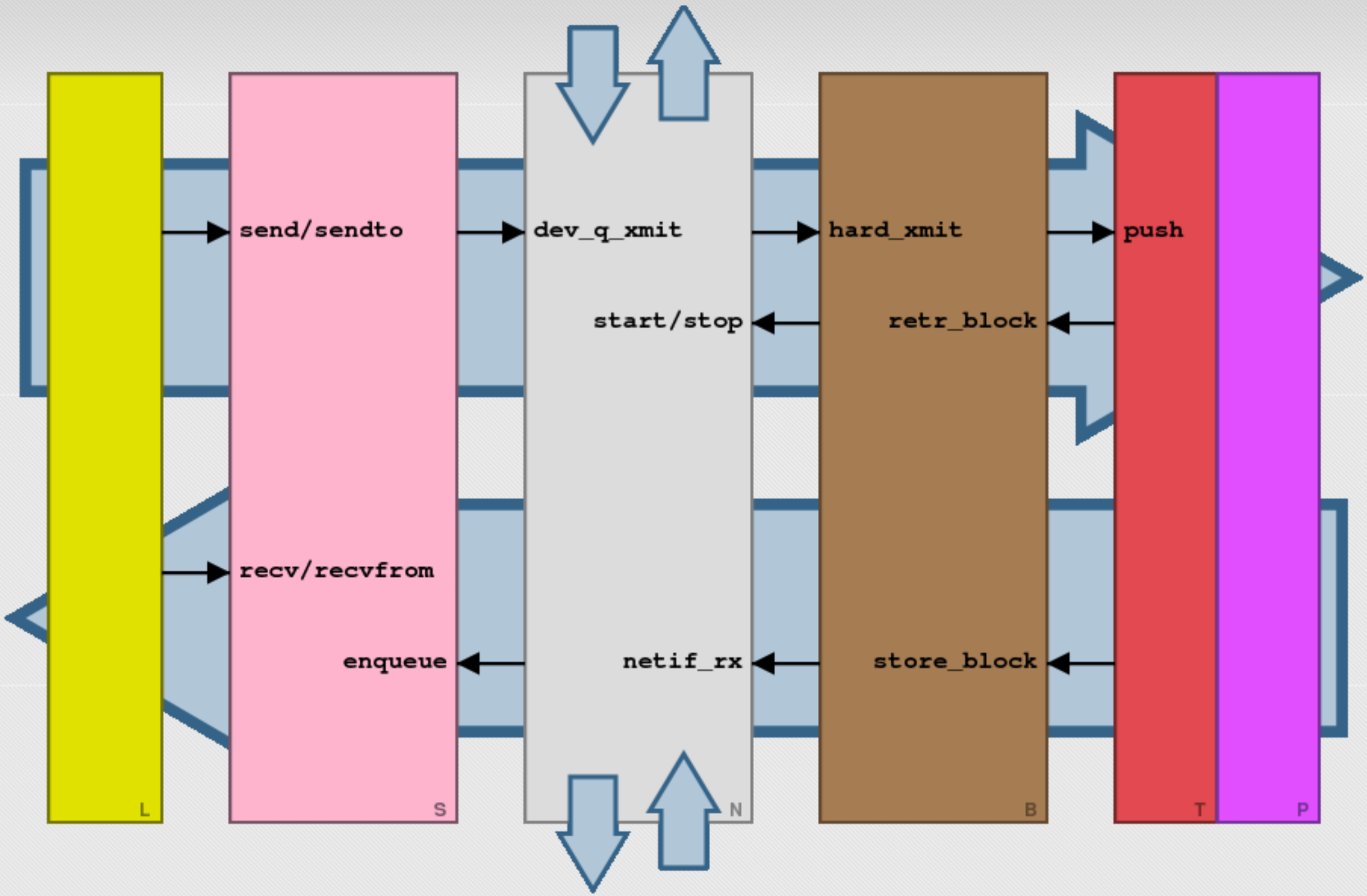
Mapping Socket Types to ZIO



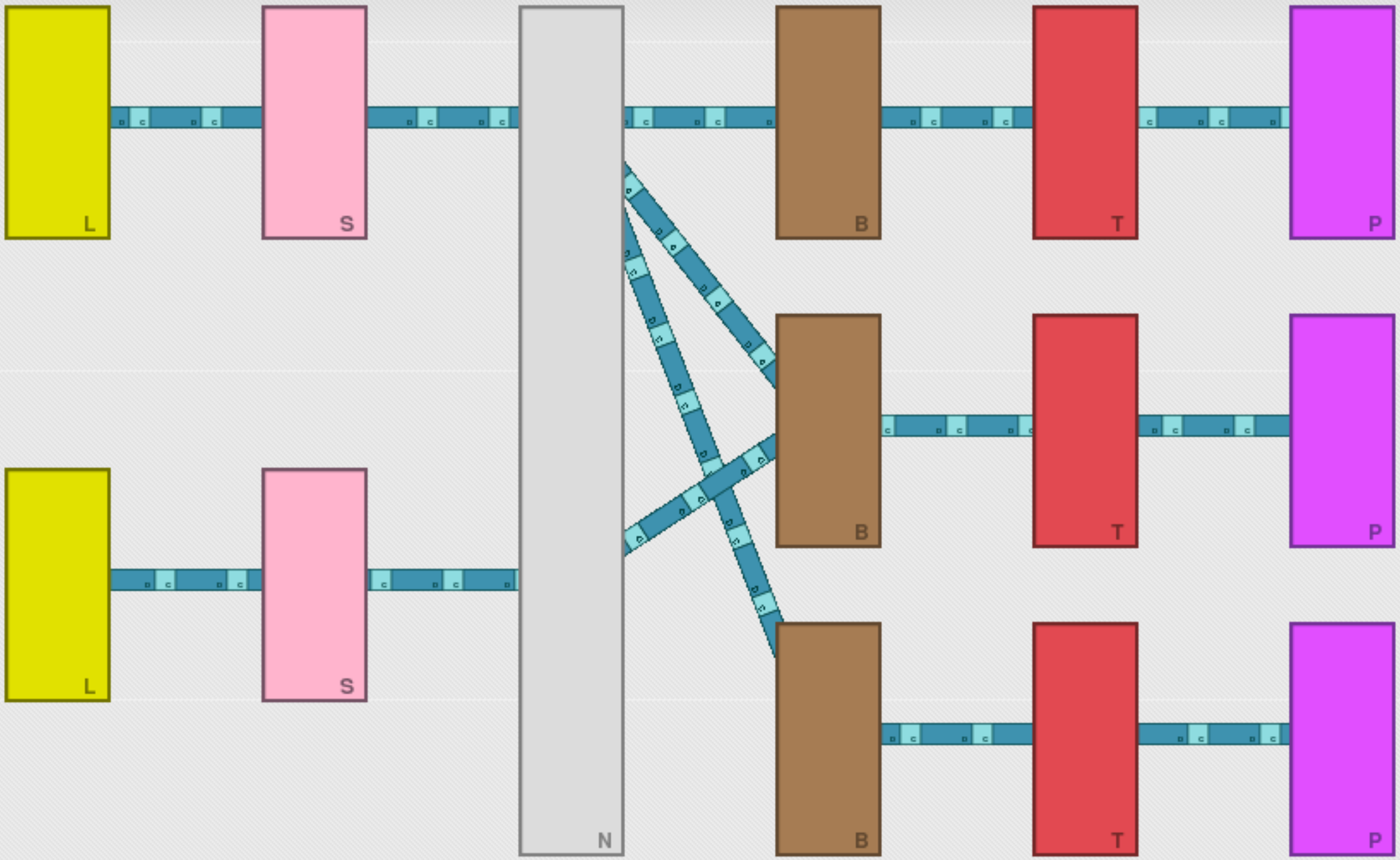
We map the three standard socket types to ZIO blocks

- The code is implemented as a ZIO buffer
- Triggers and Peripheral drivers are unaffected

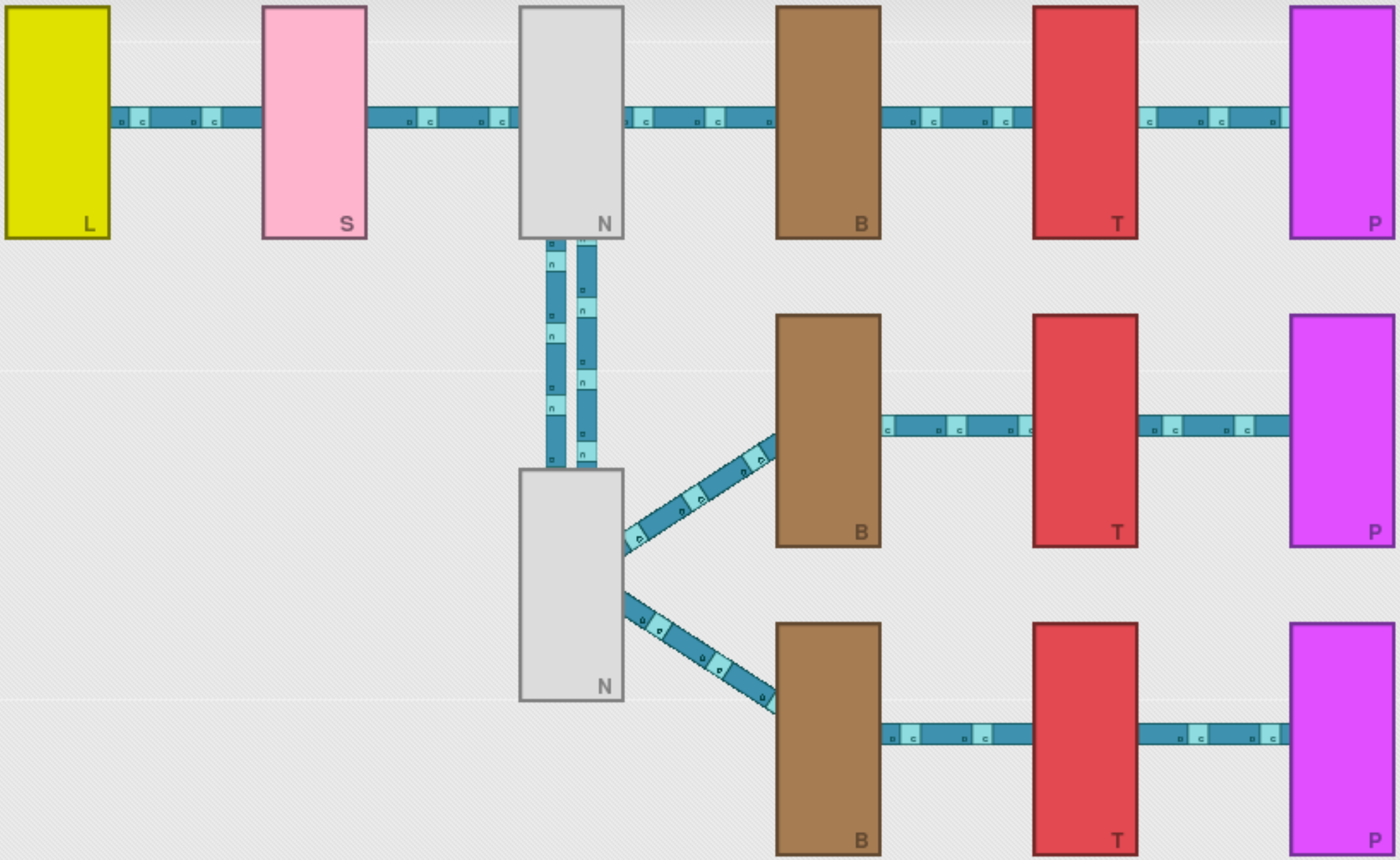
The ZIO pipeline, with zio-buf-sock active



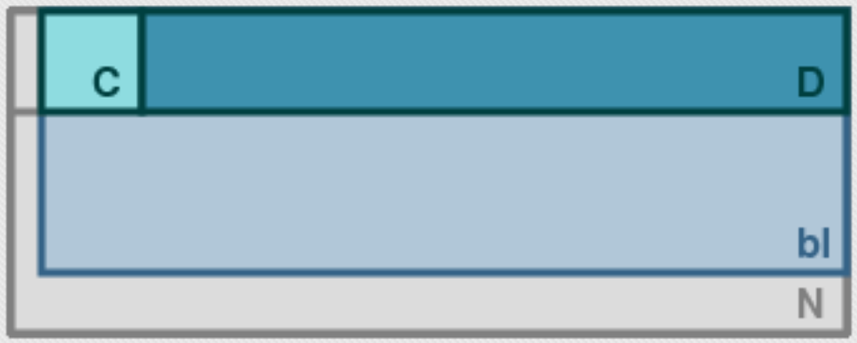
Communication Paths Within a Host



Communication Paths Across Hosts



The Internal Format of the Frame



Our frame format supports inter-host communication,

- **The "zio" network interface is an Ethernet card**
- **We carry around an Ethernet header for each block**
- **sockaddr_zio already has "host type" and "host-id"**

PF_ZIO is not (only) ZIO over Ethernet

The new PF_ZIO/AF_ZIO is not about Ethernet Frames

- The PF_ZIO address space is about I/O channels
- Frames are used to exchange I/O blocks
- Typically, the ZIO network lives inside a single host

Why using a "networkless" network protocol?

- A host may need to drive hundreds of channels
- Sockets prove better than many char devices
- Zero-copy networking helps with high data rates
- Sniffing is a boost during debugging

(ETH_P_ZIO is just a special case of the idea)

Implementation Status

device: zio-zero (input and output)
device: zio-loop (for stress-testing and diagnostics)
device: line discipline (input: UART or pty for stress-test)
device: GPIO (input and output)
device: AD7888/AD7887 (SPI ADC)
device: fmc-based TDC/DTC
device: fmc-fine-delay (input and output: 10ps resolution)
device: fmc-based 100MS ADC
  trigger: kernel timer
  trigger: high-resolution timer
  trigger: transparent trigger (user/device driven)
  trigger: external interrupt or external GPIO
buffer: "kmalloc"
buffer: "data" (SOCK_STREAM alike, coalescing blocks)
buffer: "vmalloc" (mmap-capable)
  sockets: SOCK_DGRAM and SOCK_RAW (sock STREAM almost working)
tools: zio-dump (control and data)
tools: zio-cat-file (demonstrating mmap for input channels)
tools: pfzio-send and pfzio-receive (like netcat)

Thank you for your attention

http://www.ohwr.org/projects/zio

git://ohwr.org/misc/zio.git

http://www.ohwr.org/projects/zio/documents
http://www.ohwr.org/projects/zio/wiki

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