Optimization of Event-Building Implementation on Top of Gigabit Ethernet

IEEE Real-Time conference 2005

Benjamin Gaidioz Artur Barczyk Niko Neufeld Beat Jost

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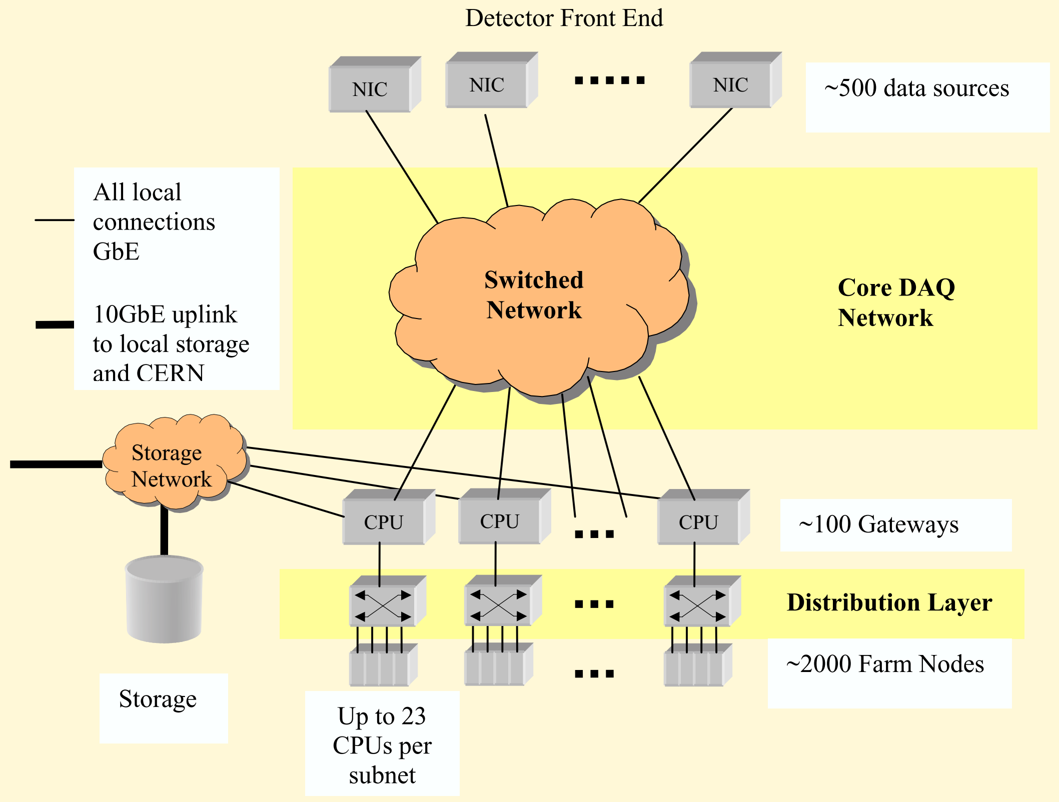

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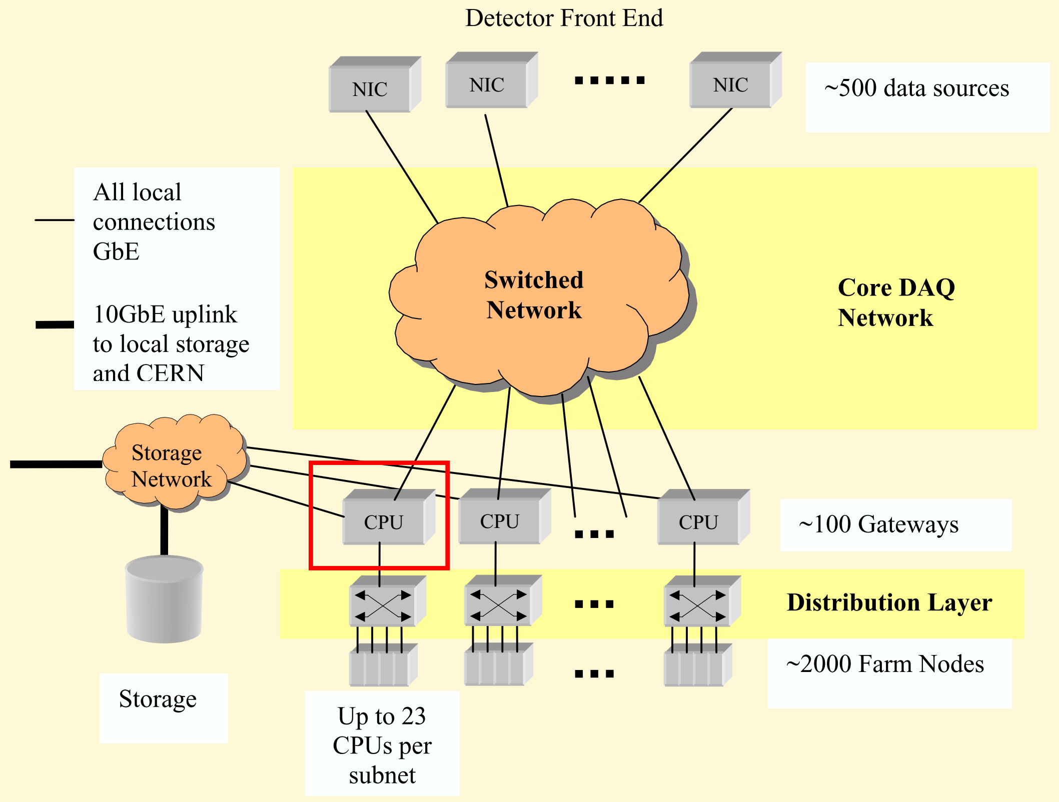

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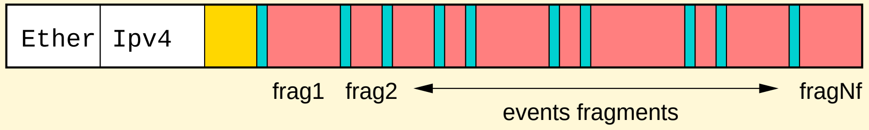

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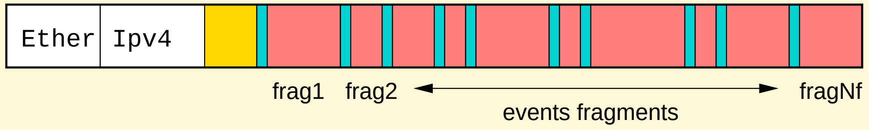

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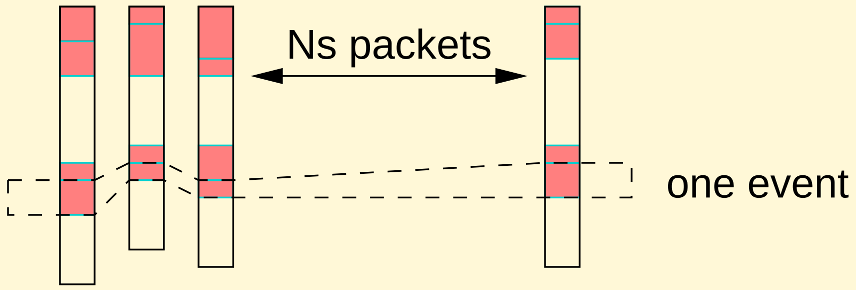

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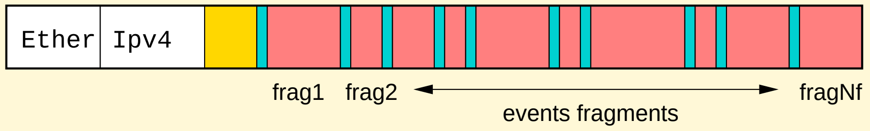

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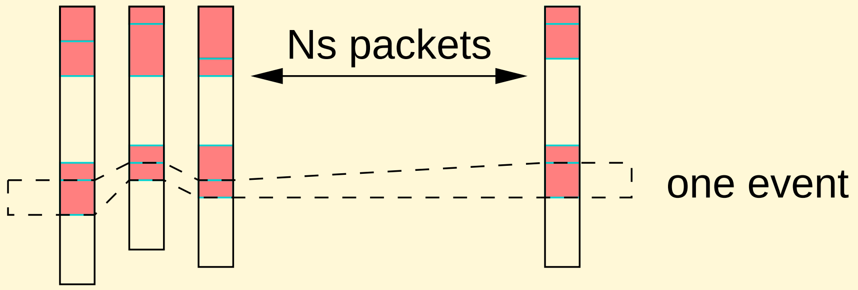


- a gateway reassembles fragments and sends them to computing nodes
- L1 events: about 4.5 KB, HLT events: about 30 KB.

outline

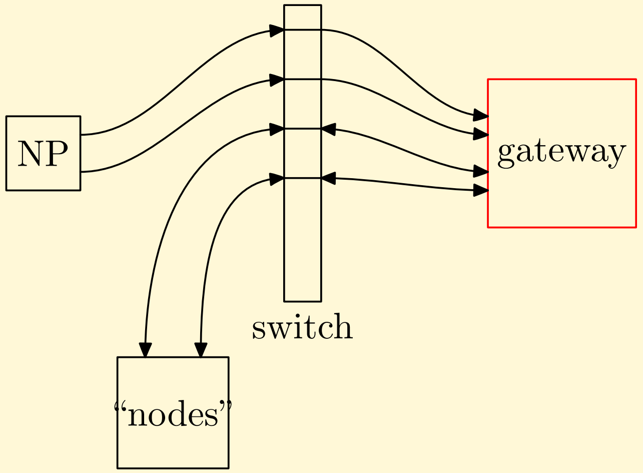
We want:

- predictability (latency constraints),
- good input/output rate $\longrightarrow$ larger “sub-farms”,

- goals of this presentation:
  - describe the implementation of the (software) component LHCb event-builder,
  - show bottlenecks and possible improvements,
  - tell about our experience with various implementation details, system settings,

system

- The host tested here is a high performance PC:
  - a dual AMD Opteron 2.2 GHz,
  - standard Linux kernel 2.6.11,
  - dual port GbE NICs: Intel 82546EB and Broadcom BCM5704.



- LHCb-like traffic is generated by a network processor,
- computing nodes are emulated by an other host.

implementation on SMP

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- two main tasks:
  1. receiving, checking and ordering data packets,
  2. sending built events, managing the nodes.

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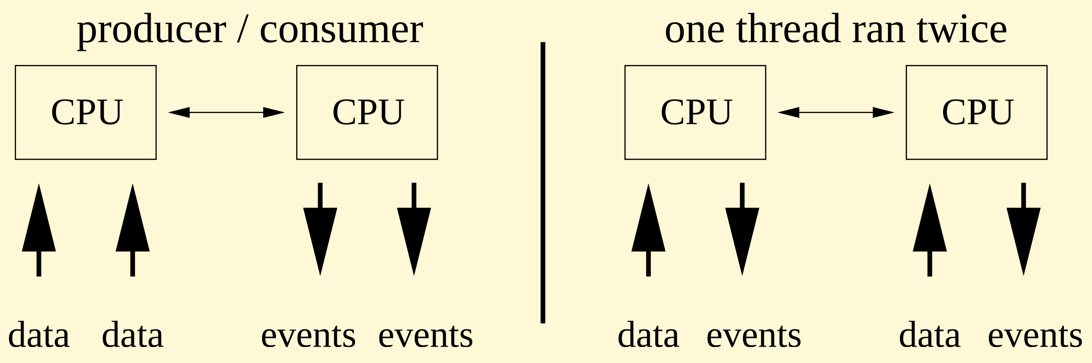
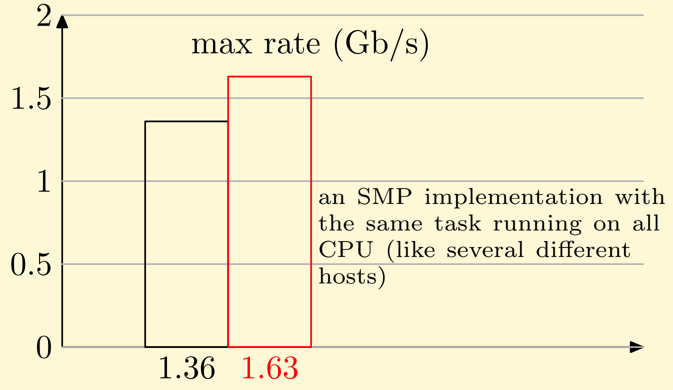
- we compare here two implementations:



performance

- improvement with a single threaded implementation:



- in the producer/consumer implementation:
  - not a lot of shared code sections (good),
  - data is moved from CPU_0 cache to CPU_1 cache (bad),

memory management

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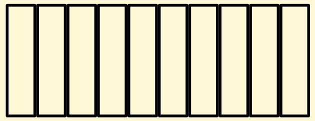

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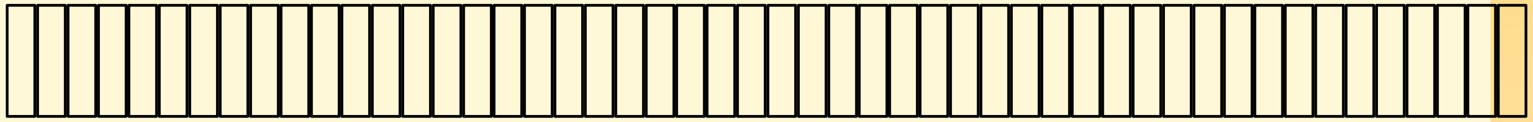

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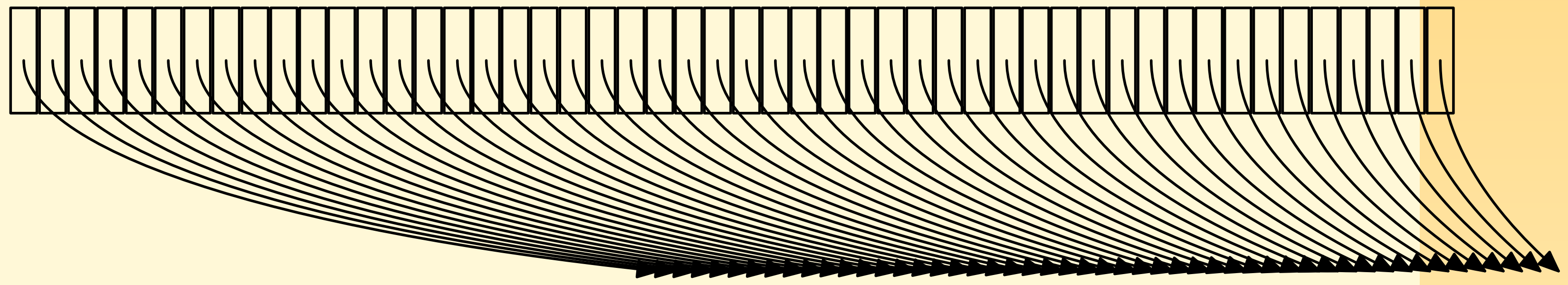

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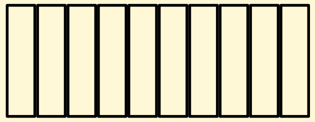

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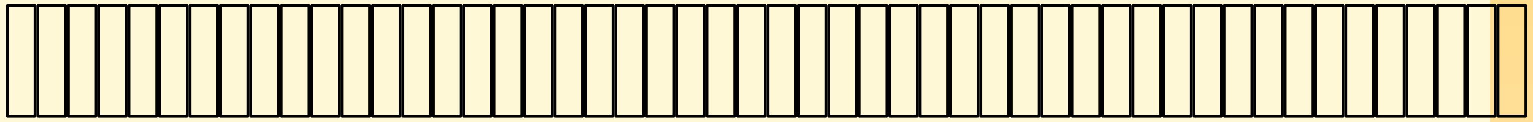

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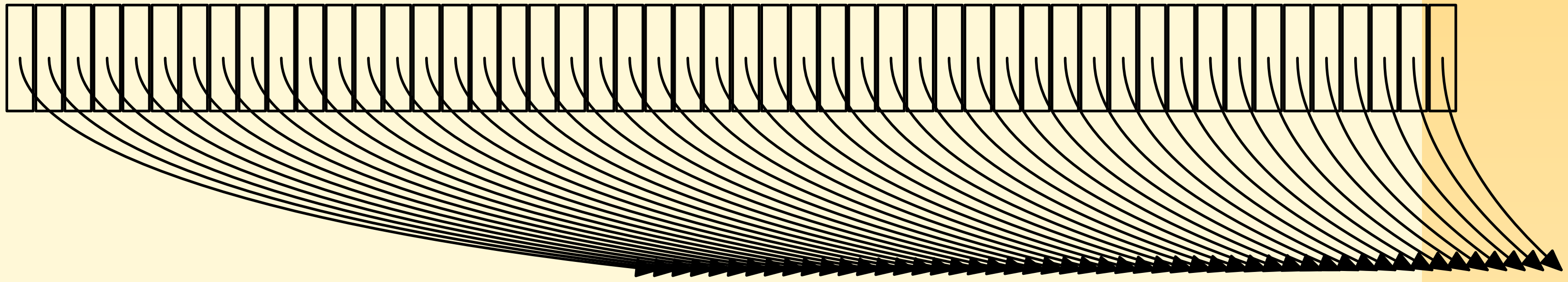

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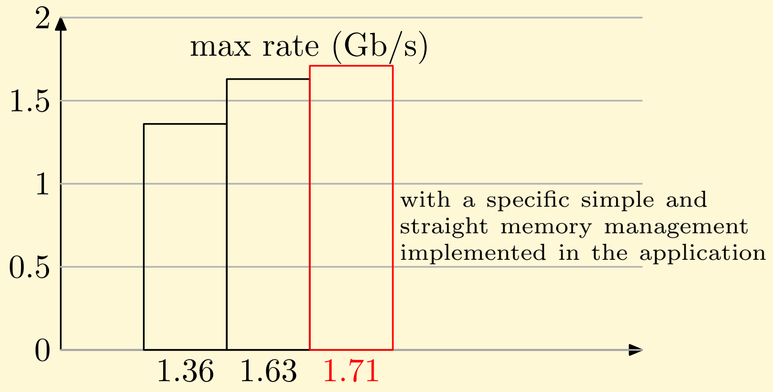
- two implementations: `stdlib` or custom memory management.

Performance

- results:

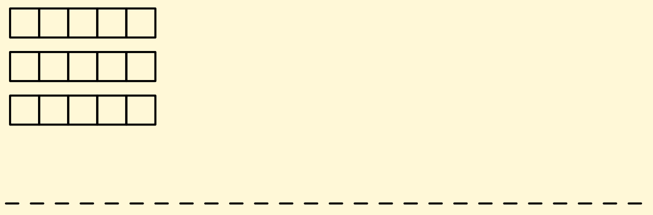


- cost of `stdlib`:
  - *malloc*, *realloc* and *free* request and give back memory pages from the operating system,
  - the operating system *clears* pages before giving them (privacy).
- performance improves a bit
- predictability: no more system calls, constant cost.

memory copies

using *sendmsg*

- many small fragments are packed into a single large message (for sending),
- standard way: using `iovec` arrays,



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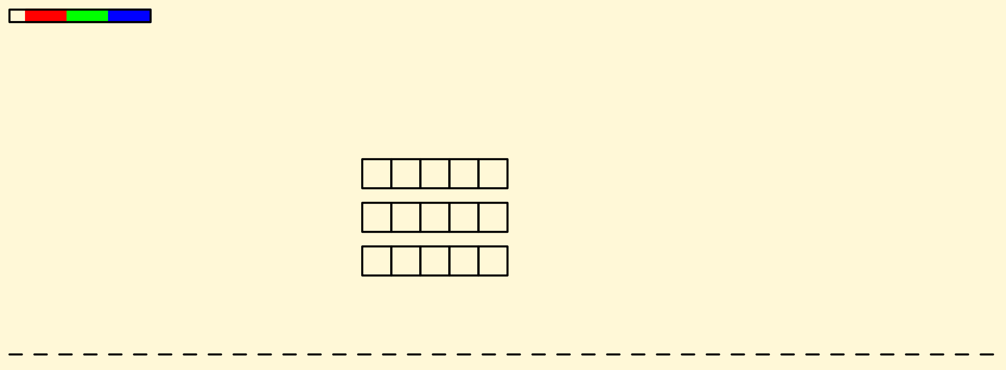

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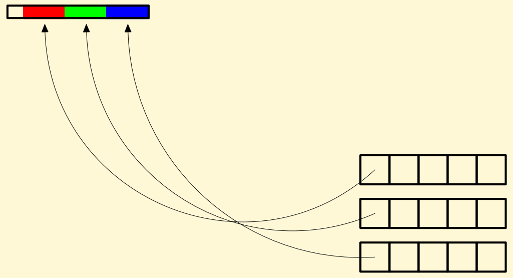

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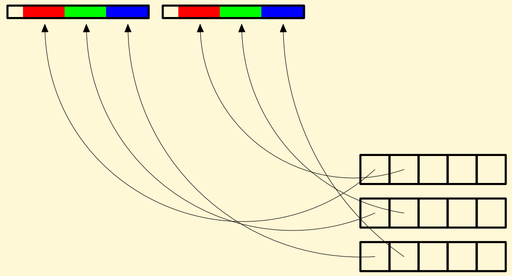

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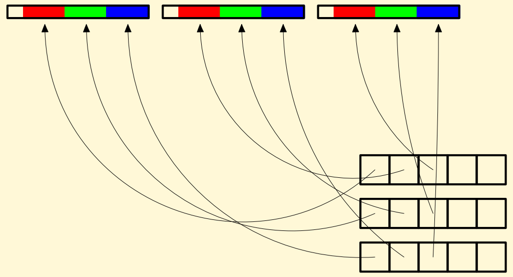

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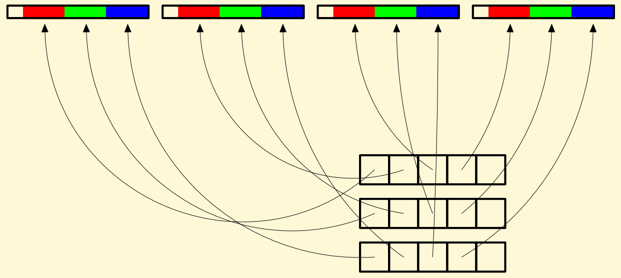

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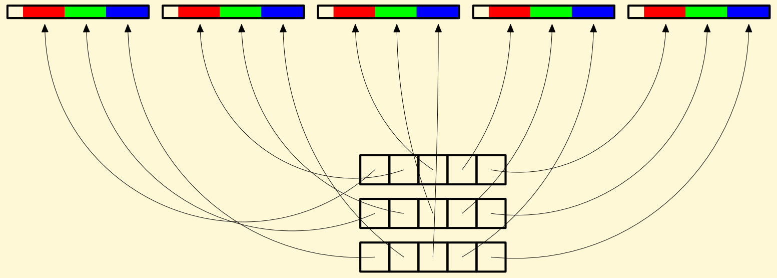

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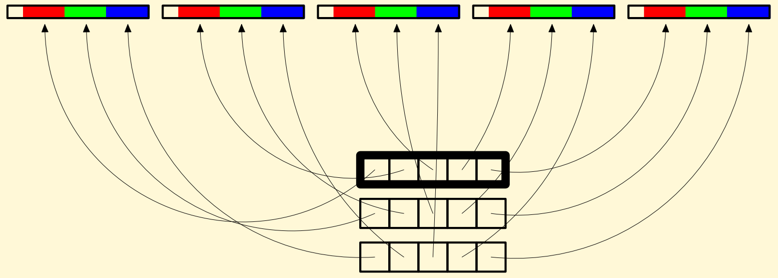

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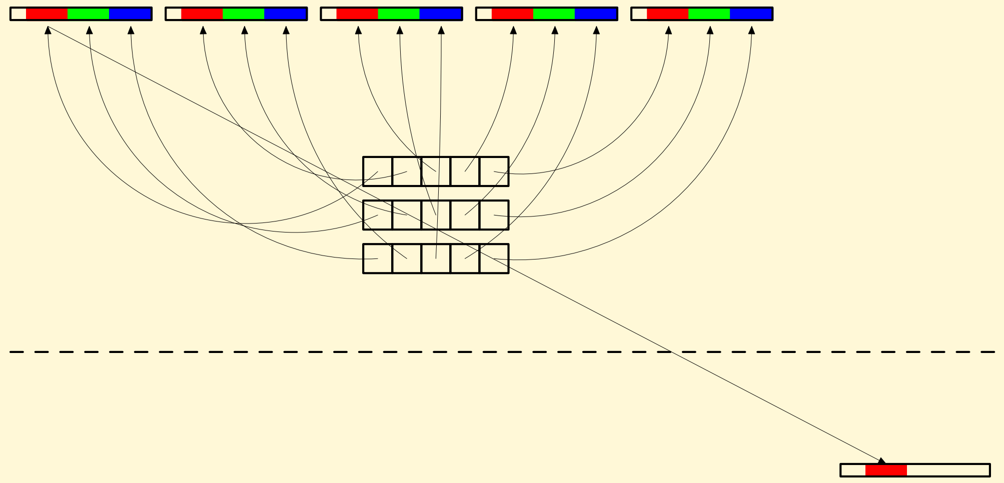

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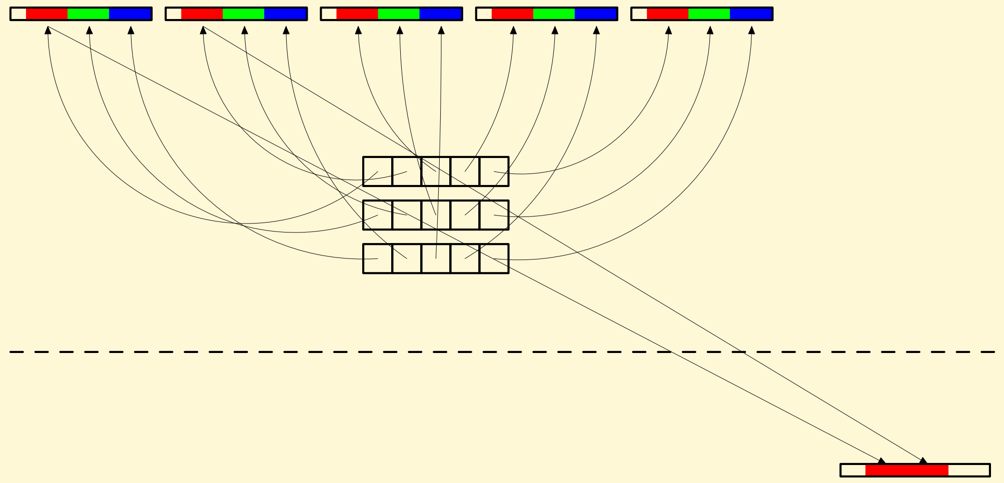

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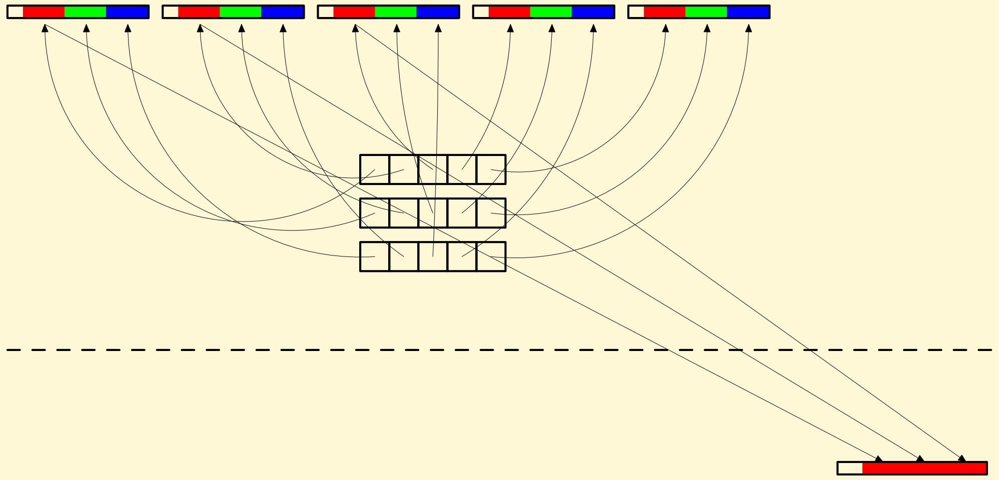

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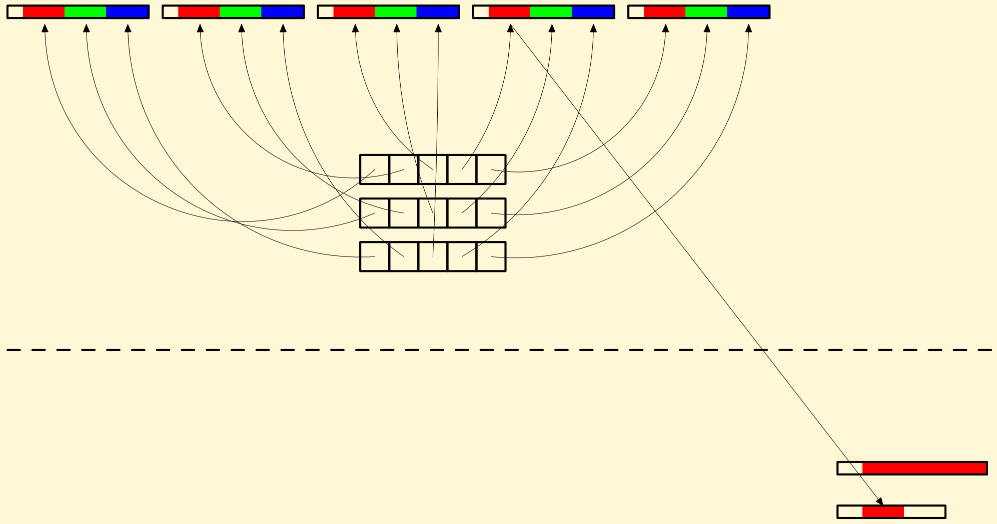

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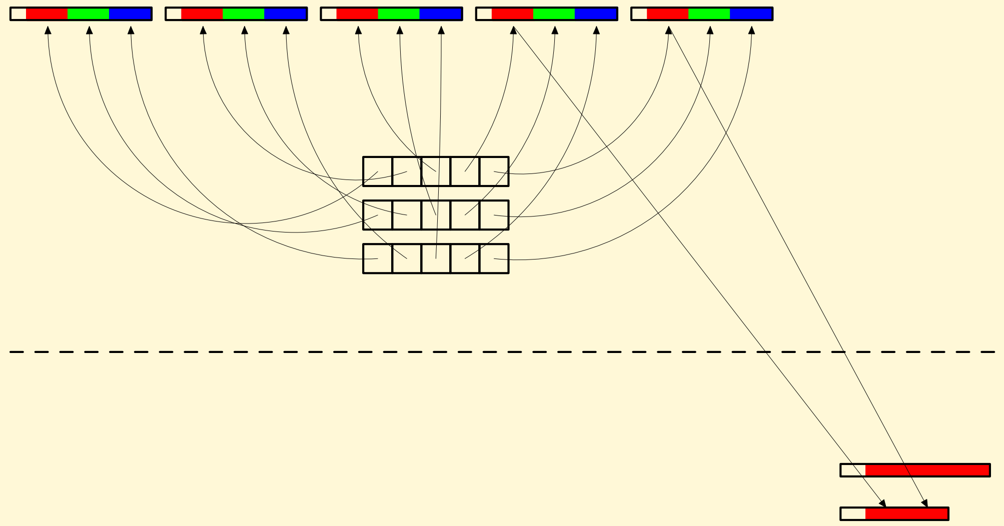

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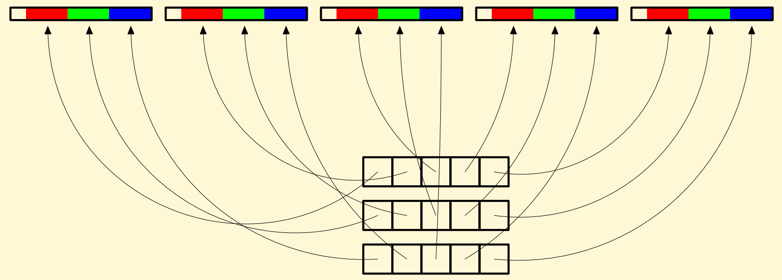

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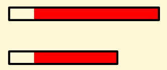

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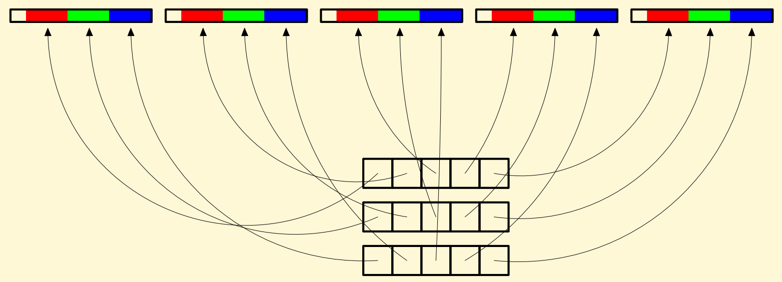
copies done by the operating system

- the system call loops over the array and copy each user-space fragment into a kernel buffer,
- involves:
  - one call to *memcpy* (kernel implementation),
  - checking that the *from* location is lying in the process address range,
- checkings are implemented *in software*. (In a system call, if *from* points in kernel space, the CPU does not fault.)
- this is a lot of overhead for just a few bytes per fragment.

copies done in userspace

- prepare the Ethernet frames in user-space



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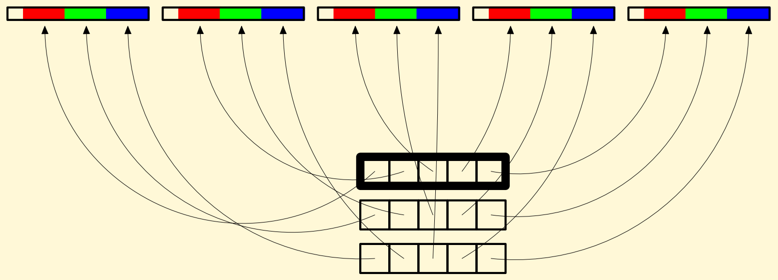

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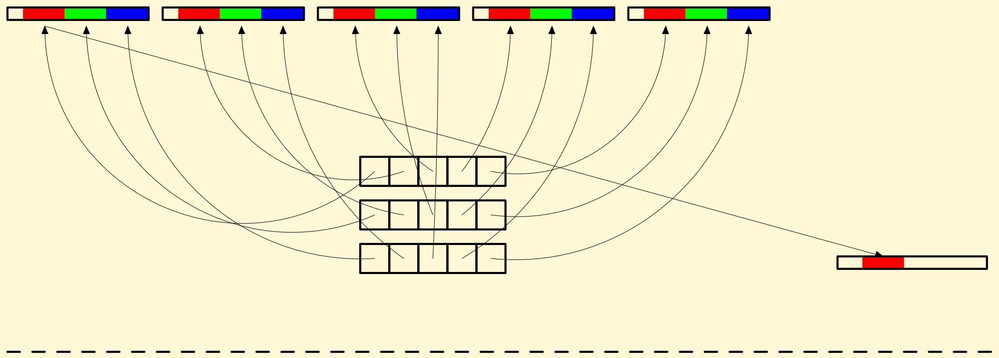

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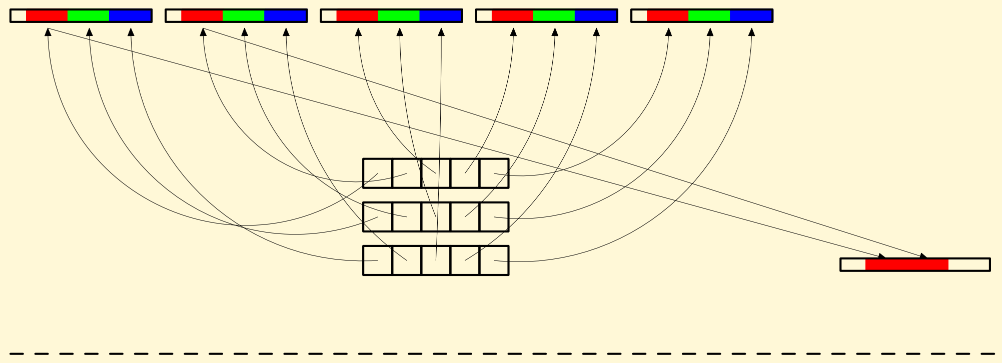

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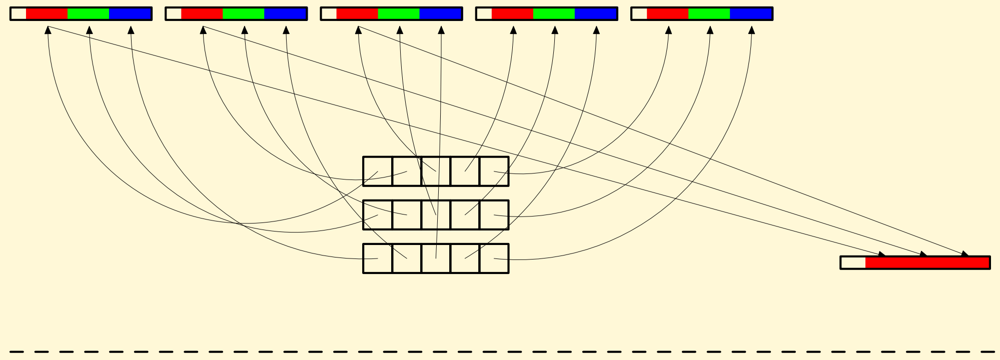

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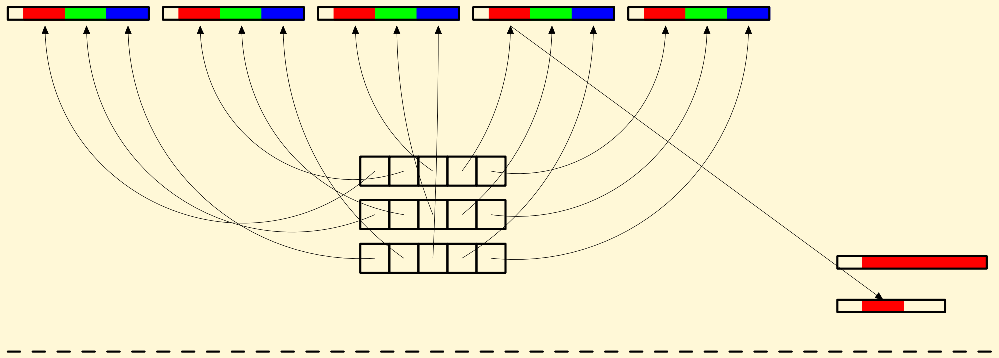

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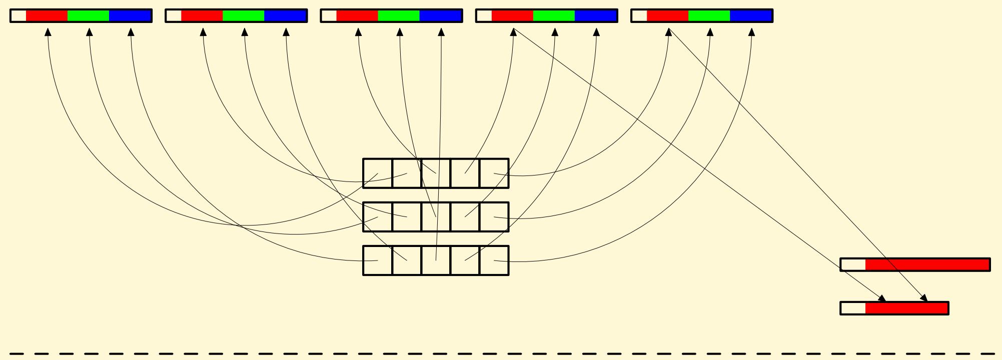

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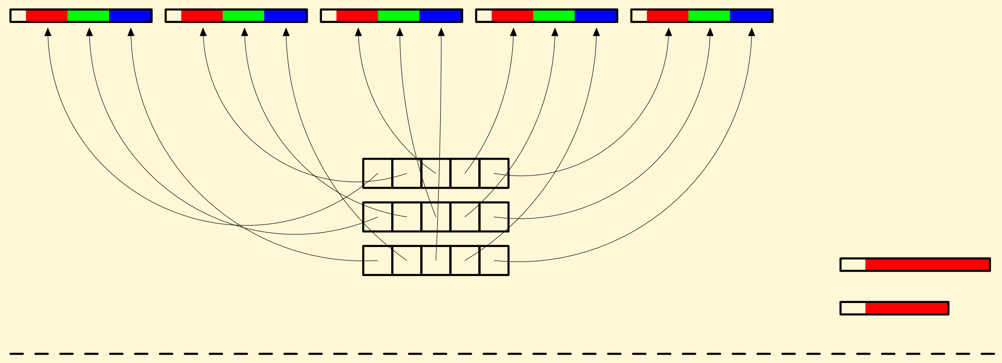

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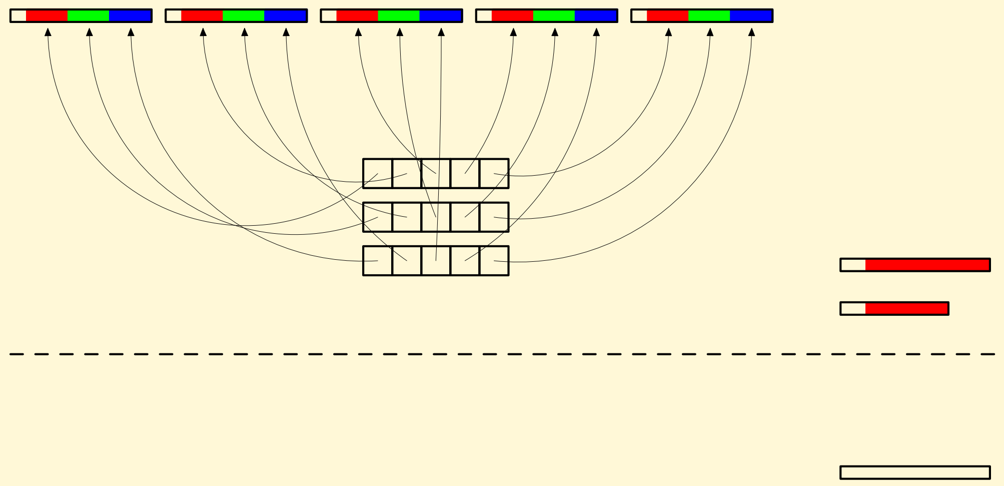

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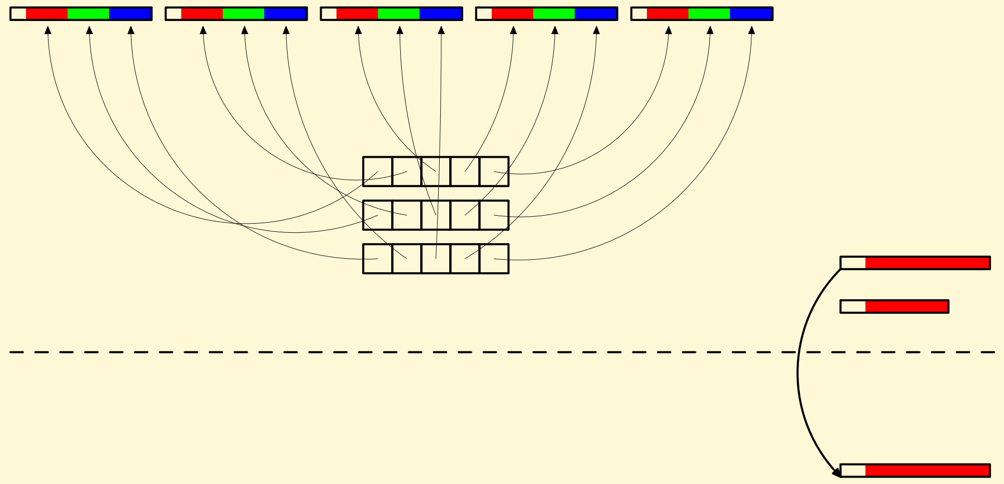

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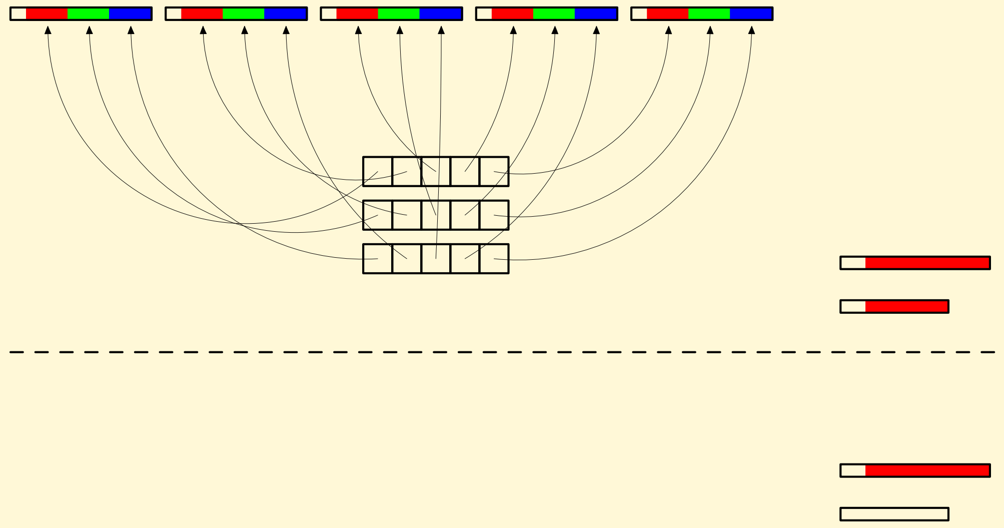

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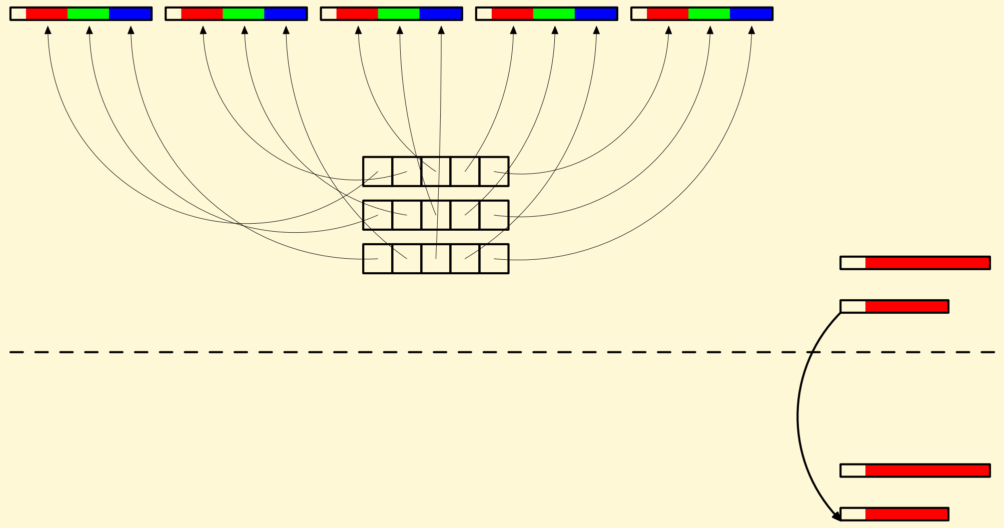

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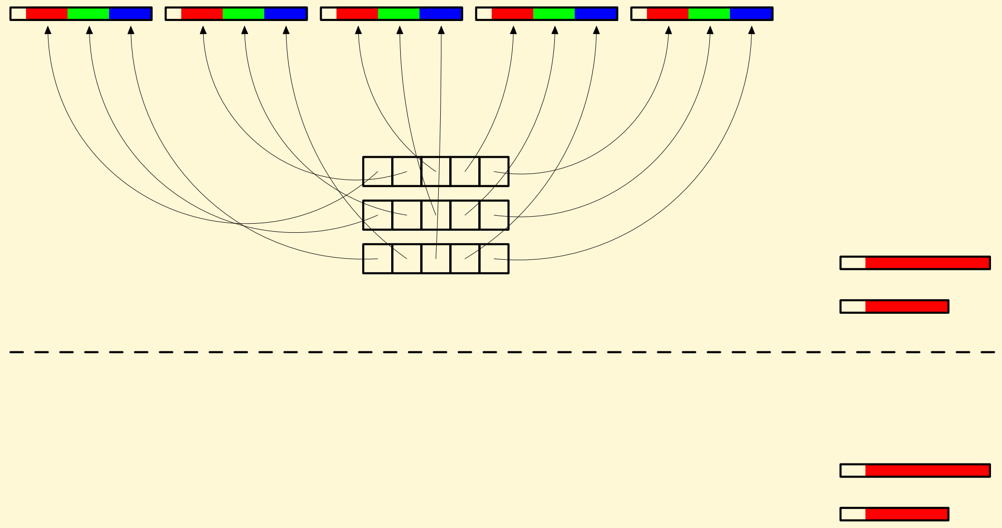

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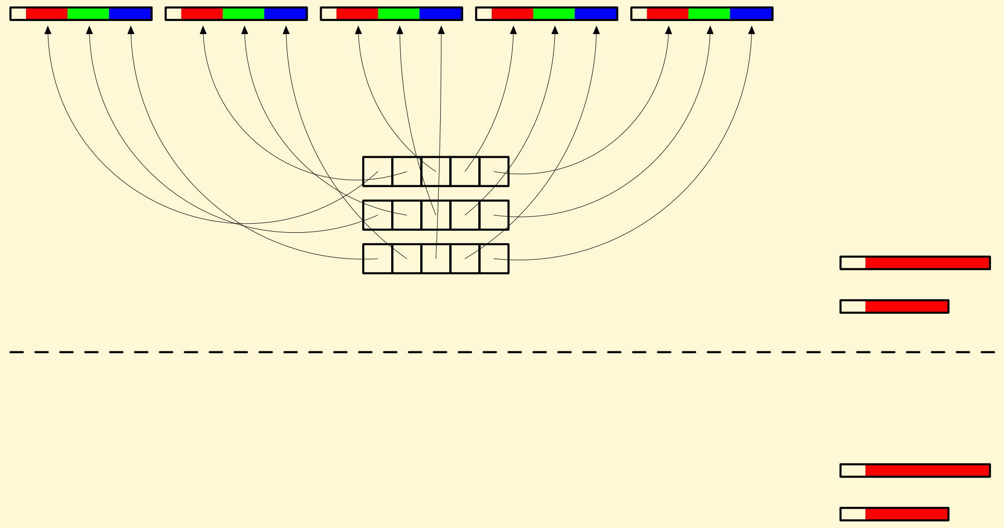

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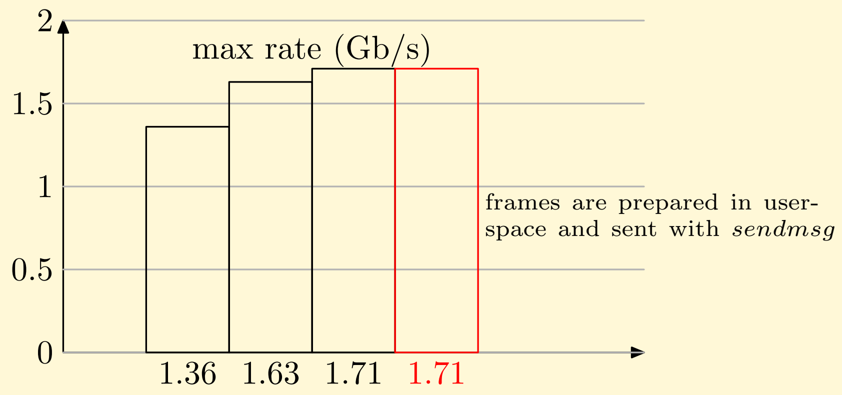

- same performance: we save and then loose CPU.

zero-copy sending

- how to save the new memory copy to kernel space?

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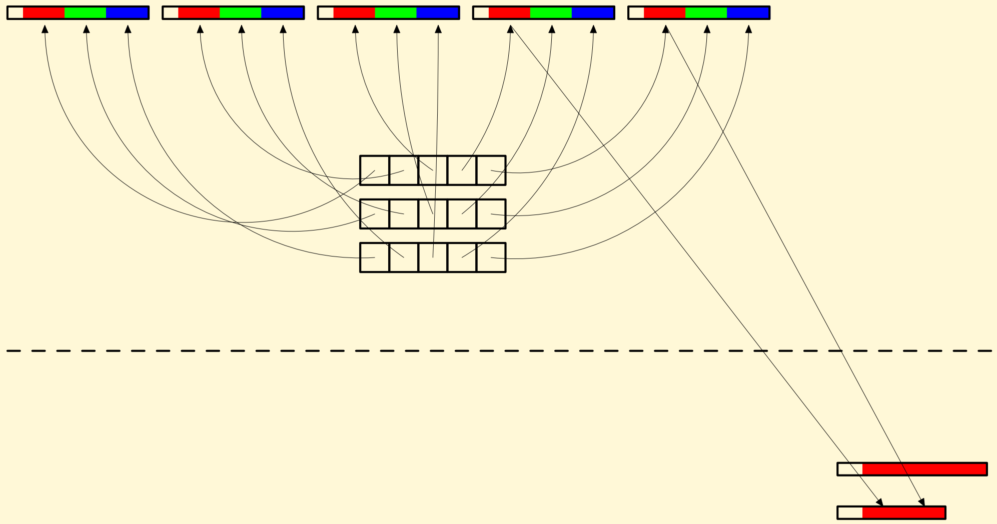
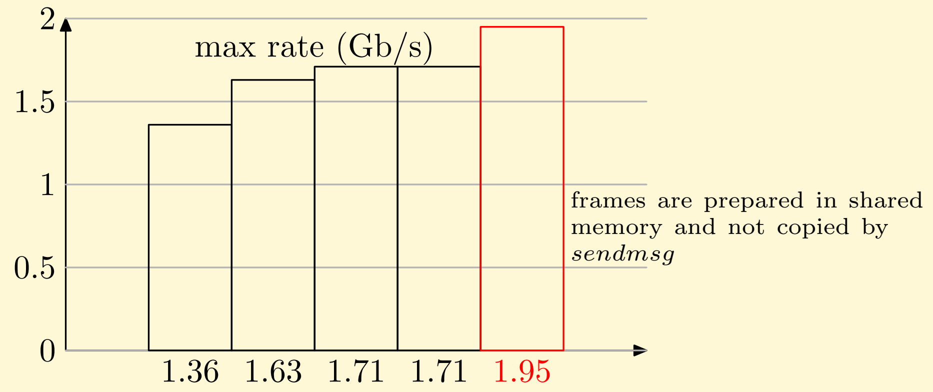
- how to save the new memory copy to kernel space?
- we build frames in *shared memory space*,
- extension of the operating system (kernel module):



  - based on raw packet socket (`af_packet.c` is a good starting point),
  - (*mmap* to share memory pages with the kernel).
- *send* implementation: the buffer is already in kernel space, add it as a DMA fragment to the frame descriptor,

performance

- it is nice to save memory copies:

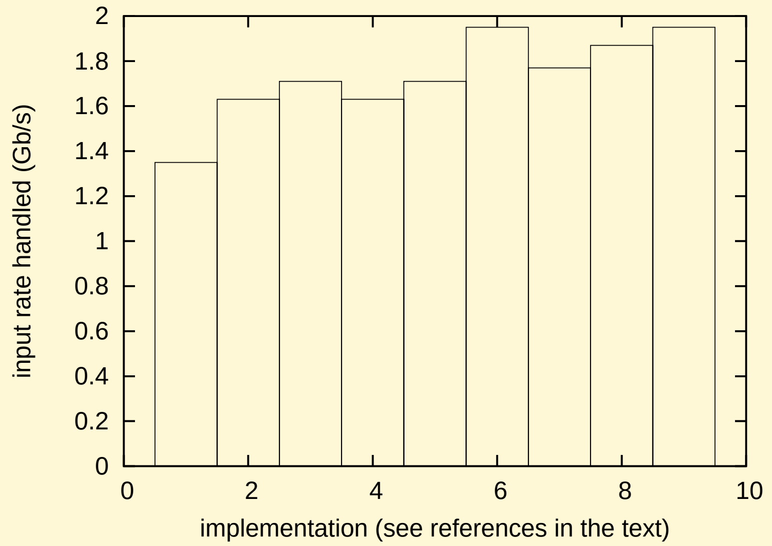


- (zero-copy receiving has not been implemented.)

summary and conclusion

summary

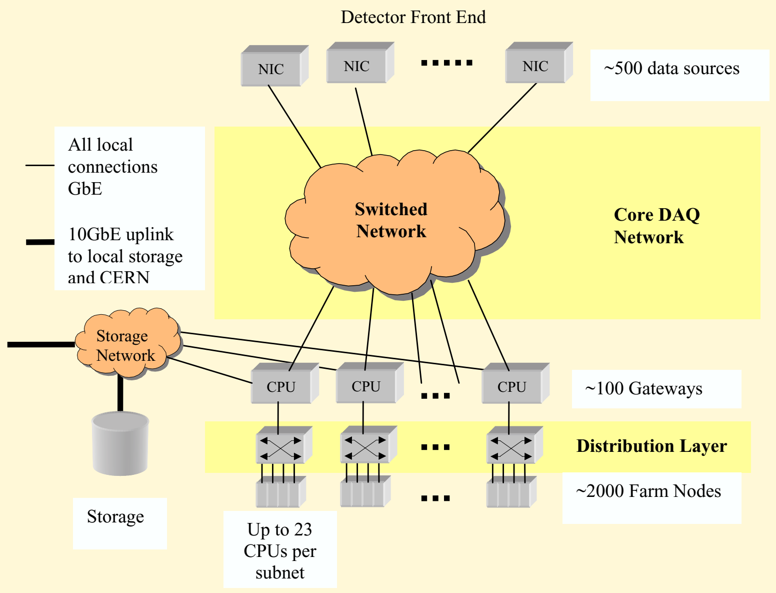
- application studied here: LHCb event-builder,



- improvements of performance and predictability with *careful implementation*:
  - SMP implementation,
  - optimized *memcpy*,
  - study of the operating system,
  - extensions to the operating system.
- (. . . and specific system settings.)

conclusions

- LHCb event-building can be implemented with a lower number of gateways.



- careful look at hardware and operating system source code is *really important* for both performance and guarantees:
  - helps in increasing performance,
  - no surprises during execution.
- (see also poster P8-1 for performance of NIC)