# Efficient Implementation of Dynamic Protocol Stacks in Linux

*WM: Maybe:Dynamic and flexible configuration of Efficient Linux Protocol Stacks; maybe, i'll get a better idea; it's not very trendy*

Ariane Keller
ETH Zurich, Switzerland
ariane.keller@tik.ee.ethz.ch

Daniel Borkmann
ETH Zurich, Switzerland
HTWK Leipzig, Germany
dborkma@tik.ee.ethz.ch

Wolfgang Mühlbauer
ETH Zurich, Switzerland
muehlbauer@tik.ee.ethz.ch

## ABSTRACT

TODO: rewrite abstract - beginning is copied from an old paper... Future network architectures aim at solving the shortcomings of the traditional, static Internet architecture. In order to provide optimal service they have to adapt their functionality to different networking situations. This can be achieved by dividing the networking functionality into modular blocks and combining them as required at runtime. In this paper we address the performance aspect of such architectures and we show that their performance is comparable with the performance of a standard Linux protocol stack.

*WM: I tried to think about an abstract, see next paragraph. Feel free to change ... It's a little bit long, but first sentence can be dropped, etc. Maybe, it's also useful for the intro* Beyond doubt, the Internet has grown out of its infancy. Yet, network programming is still widely understood as programming strictly defined socket interfaces. Only some frameworks (e.g., ANA, Click, Active Networking) have made a step towards *real* network programming by decomposing networking functionality into small modular blocks that can be assembled in a flexible manner. In this paper, we tackle the challenge of accomodating 3 partially conflicting objectives: (i) high flexibility for network programmers and network application designers, (ii) re-configuration of the network stack at runtime, and (iii) high packet forwarding rates. First experiences with a prototype implementation suggest little performance overhead compared to the standard Linux protocol stack.

## 1. INTRODUCTION

Some references that might be useful: [3] (ANA) and [7] (Click) and [4] (From protocol stack to protcol heap: role-based architecture) and [5] (PLUTARCH:an arbument for network pluralism) and [1] (netgraph) and [8] (survey of next generation internet) and [6] (xKernel) and [9] (model for flexible high-performance communication subsystem). - should we explicitly say something on active networking or should we try to avoid it completely?

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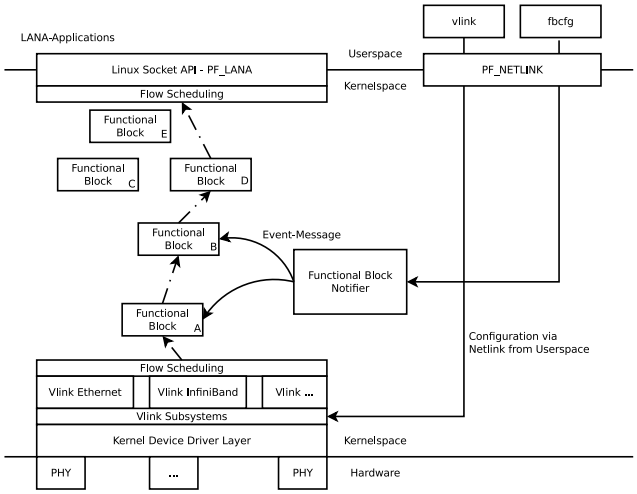


**Figure 1: Lana architecture**

# 2. LIGHT WEIGHT AUTONOMIC NETWORK ARCHITECTURE (LANA)

LANA provides a framework for setting up protocol stacks not known by todays standard operating systems. Within LANA it is also possible to change the protocol stack at runtime, without communication teardown or application support. These properties build the basis for a networking system that provides protocol stacks that are better targeted to a networking situation than the well known TCP/IP protocol stack.

Similar to the Protocol Stack of Linux the protocol stack of LANA is implemented in kernel space and applications can access it over a socket interface. The hardware is hidden between a virtual interface. This interface allows on the one side to plug in different network technoligies such as Ethernet or bluetooth and on the other side functional blocks to have a unified interface. Additionally, virtual networks, similar to VLANs can be built and managed with the standard tools ( `ifconfig, ifpps, ethtool`. (TODO: descirbe the vlink subsystem better).

The control flow between the functional blocks is done with *events*. They are used for setup and teardown of data flow paths between the functional blocks. (TODO: something else?, anything more specific (how is the subsystem called of the Linux Kernel?))

Data is transmitted between the functional blocks by function calls. Each functional block either calls the processing function of an other functional block or discards the data and returns. There are two special functional blocks - those communicating with a network driver and those communicating with the sockets. Additionally the can put the packets either in the drivers transmit queue or in the sockets receive queue. (TODO: better description of processing engine, backlog queue)

## 2.1 Configuration Interface

The protocol stack can be configured from user space with the help of a command line tool. The most important commands are summarized below.

- `add`, `rm`: Adds (removes) a functional block from the list of available functional blocks in the kernel.
- `set`: sets properties of a functional block with a `key=value` semantic
- `bind`, `unbind`: Binds (unbinds) a functional block to another in order to be able to send messages to it.
- `replace`: Replaces one functional block with another functional block. The connections between the blocks are maintained. Private data can either be transferred to the new block or dropped.
- `subscribe`, `unsubscribe`: Subscribes (Unsubscribes) one functional block to receive control messages from another functional block.

## 2.2 Improving the Performance

During the implementation of our framework we have evaluated different possibilities for the integration of our packet processing engine with the Linux kernel. We think the insights gained are interesting for other researcher that have to do fundamental changes on the Linux protocol stack and hence, we summarize them here. Our goal was to be able to process as many *minimum sized Ethernet frames* as the Linux kernel is able to process. In order to compare the performance of the Linux Kernel and the performance of our engine we have dropped all packets in the Linux Kernel protocol stack as soon as they were arrived (TODO: where exactly?). In our system the packets were processed by the fb_eth functional block followed by two fb_dummy functional blocks that were simply forwarding the packets. We can distinguish the following three approaches:

- On each CPU there exists one high priority thread that is responsible for processing LANA packets. This approach leads to a starvation of the interrupt handler (ksoftirqd) and hence the maximal achieved packet rate is only about half as what is achieved by the protocol stack of the Linux kernel. Also changing the priority of the LANA thread to normal only slightly increases the throughput.
- Instead of relying completely on the Scheduler of the Linux Kernel we control preemption and scheduling explicitly. This approach still exhibits scheduling overhead, but it increases the performance to about two thirds of the performance of the Linux Kernel.
- Instead of executing the LANA functions in a dedicated thread they are executed directly in the ksoftirqd function. With this approach approximately 95% of the performance of the Linux kernel is achieved.

The corresponding numbers are listed in Table 1.

| mechanism | performance |
|---|---|
| dedicated kernel thread (high priority) | 700000 |
| dedicated kernel thread (normal priority) | 750000 |
| dedicated kernel thread (controlled scheduling) | 900000 |
| execution in ksoftirqd | 1300000 |
| Linux kernel stack | 1380000 |

**Table 1: Performance evaluation (pps) of different approaches to receiving packets in the Linux kernel. The packets are 64 Bytes long. The evaluation was done on a TODO: CPU/RAM/NETWORKCARD/KERNEL**

## 2.3 Software Available

The current sofware is available under the GNU General Public License from [2]. In addition to the framework it also

includes four functional blocks: Ethernet, Berkeley Packet Filter, Tee (duplicate a packet), and Forward (an empty Block that just forwards the packets to another block). The framework does not need any patching of the Linux kernel but needs a new, 2.6.X kernel.

# 3. CONCLUSIONS AND FUTURE WORK

We have shown that it is possible to implement a flexible protocol stack that has a similar performance than the default protocol stack in the Linux kernel. This allows for the easy inclusion of new, still to be developed protocols and for the change of the protocol stack at runtime to include for example compression or encryption as the networking conditions change.

In the short term we will compare the performance of real scenarios implemented in our system with the performance of an implementation in other systems (for example default Linux protocol stack or the Click router). In the midterm we will develop a mechanism that automatically sets up a protocol stack for an Application whereby the Application can specify some characteristics the communication channel should have, but not exactly how this has to be achieved. For example the application could require a "reliable communication channel" and a controller would choose between different protocols that provide reliability (e.g., one for wired communication, one for wireless communication, one for wireless, multi-hop communication). The setup of the protocol stack will have to be negotiated between the source and destination node. The end goal will be to have a networked system that requires less configuration as compared to todays networks and that is able to adapt itself to changing network conditions.

# 4. ACKNOWLEDGMENTS

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