Avoid Development Hell to Realize Software ROI

White Paper

6WIND

High Performance & Secure
Networking Solutions

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Executive Summary

With new emerging technology recruitments like 5G, IoT, SD-WAN, the network equipment manufacturers and telecom equipment providers are investing in building and designing new networking products.

With the expansion of data consumption and the need for high performance and flexibility of deployments driven by the new emerging technology requirements (5G, IoT, SD-WAN), more and more network equipment manufacturers and telecom equipment providers are investing in building and designing new networking products.

The new networking products are capable of leveraging, in the most efficient way, the computation performance provided by new available generic hardware platforms and the deployment options used to deliver the right level of performance through public clouds infrastructures.

They do this by deploying virtualized services closest to the end customers (containerizations).

When building a new networking product, whatever the complexity, manufacturers have always the choice to build or buy. Building comes usually with a lot of development considerations, not only costs but also time to market, risk mitigation, and maintainability. Before deciding to develop stacks internally or use off-the-shelf solutions, it is very important to understand this complexity.

In this white paper, we will highlight the challenges a build vs buy decision could involve when building a high-performance networking equipment.

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Introduction

In this white paper, we will discuss the challenges a build vs buy decision involves

The new generation of servers based on increasingly powerful multicore processors and high-speed ethernet technologies (10G, 40G, and 100G) enables the development of cost-effective network and telecom equipment using generic bare metal and virtualized servers.

Standard OS networking stacks have not been designed to extract the required level of network performance from this new generation of hardware platforms to compete with legacy architectures. Developing and maintaining a scalable networking stack optimized for multicore hardware architectures is a very complex task.

Multicore processor vendors provide a software environment to develop network applications. This software environment includesSoftware Development Kits (SDKs) needed to make the best use of hardware resources for receiving and transmitting packets. For instance, DPDK (Data Plane Development Kit)a set of libraries and drivers for fast packet processing, provides a programming framework for Intel, ARM, and AMD processors and enables faster development of high speed data packet networking applications.

Software Development Kits (SDKs) such as DPDK are mandatory to drive in the most efficient way the best performance from the hardware, but it is important to note that they are not a networking stack.

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What is DPDK?

Data Plane Development Kit (DPDK), the de-facto framework that provides standardized services for high performance packet processing.

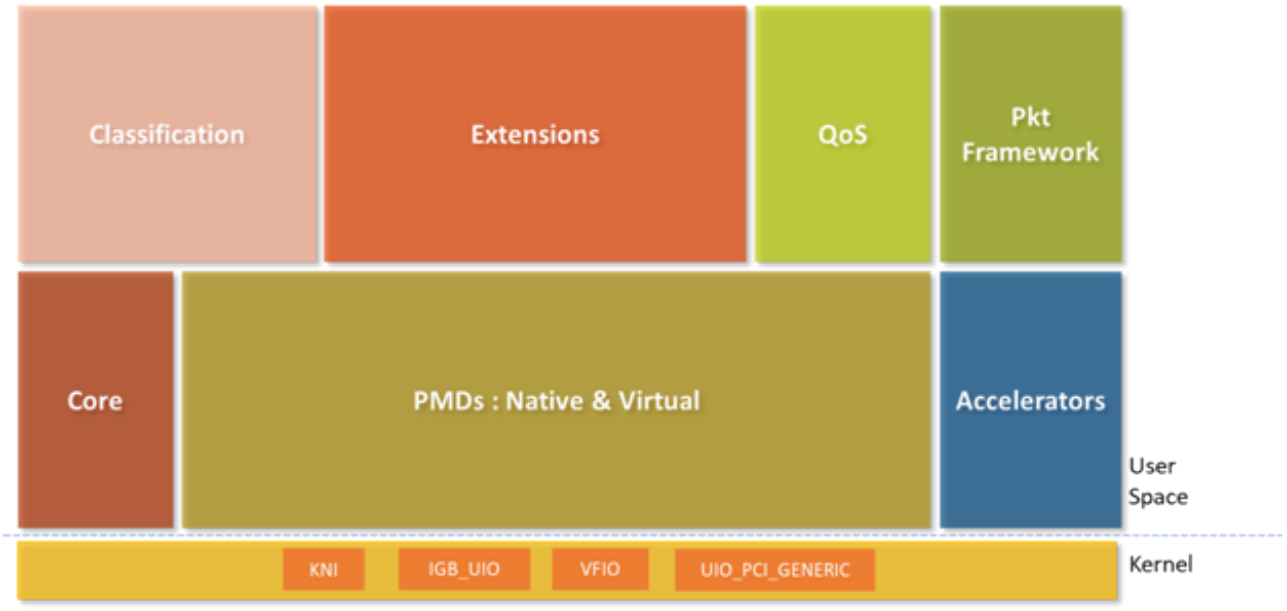
In 2013, 6WIND launched thedpdk.org(Data Plane Development Kit) open source project before successfully transferring it to the Linux Foundationin 2017. Initially designed for Intel architectures, DPDK is now the de facto framework to provide standardized services for high performance packet processing.

The DPDK framework creates a set of libraries for specific hardware/software environments through the creation of an Environment Abstraction Layer (EAL). The EAL, part of the core modules, hides the environmental specifics and provides a standard programming interface to libraries, available hardware accelerators and other hardware and operating system (Linux, FreeBSD) elements. For instance, the EAL provides the framework to support Linux, FreeBSD, Intel IA (32- or 64-bit), ARM, AMD, etc. It also provides additional services including boot support, PCIe bus access, trace and debug functions and alarm operations.

The DPDK implements a low overhead run-to-completion model for fast data plane performance and accesses devices via polling to eliminate the performance overhead of interrupt processing. Different poll mode drivers C(PMDs), native and virtual, are available to handle major HW NICs (Intel, Mellanox, Broadcom, etc.) and virtual NICs (Virtio, VMXNET3, VHOST, etc.). Besides these modules, DPDK provides also dedicated modules for offloading security functions to HW crypto engines (QAT, AES-NI. etc.), classification (ACL, HASH, etc.), QoS (Meter, Scheduler) and others extensions.

Even though DPDK is mandatory to receive and transmit packets at a very high speed, it does not include any implementation of network protocols. It only provides basic examples to explain how networking software can use the DPDK low-level services.

A networking stack of a standard operating system cannot be reused on top of DPDK because its internal architecture has not been designed to scale on a large number of cores. So, network software developers have to design andimplement from the ground up a new networking stack on top of DPDK and integrate this stack with the software environment and the management framework.



DPDK Architecture Overview

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High Performance Networking Stack Architecture Design

In this section we will review the challenges to be solved to develop this kind of software.

Required Software Skills

Developing high performance data plane software requires very specific networking and software skills. Developers must have a skill set combining embedded software background, expertise for a large number of network protocols and hardware - software integration experience. Although having practice in embedded Linux software developers need to have an in-depth understanding of how the processor works internally (not only how it can be programmed) combined with PCIe, firmware and Ethernet NIC skills. Thus, software team managers should not underestimate the learning curve for a development team to reach a good level of productivity.

At 6WIND, we train teams of embedded software engineers to develop data plane software on top of DPDK and our experience shows an experienced engineer needs between 3 to 6 months to be fully productive.

Software Design

To achieve the highest performance, developers have to use specialized techniques because high performance data plane software is very specific. Reusing available networking stacks is impossible because their architecture has not been designed to scale on multicore processors:

- Specific programming models like run-to-completion leveraging multi-core architectures must be well understood.
- Packet flow processes must be designed and optimized to minimize the number of processor cycles as Layer 3 (IP) performance and latency are directly related to it.
- Layer 3 fragmentation is an example to illustrate potential design problems. A first design of an IP stack can be done without fragmentation and it will work in 99% of the use cases. However, adding fragmentation to have a fully compliant IP stack will cause many problems such as hardware checksum offloading. IP fragments must be memorized and reordered instead of copying fragments into a linear area where all bytes fit. Multi-segment packets must be correctly implemented. Fragmentation will also have impacts in the higher layers. TCP is now getting horribly complex as you must reassemble IP fragments and TCP segments.
- Modern software stacks have also to be IPv6 compliant. Unfortunately, IPv6 is a completely different software stack compared to IPv4 (fragmentation, automatic address acquisition, end-to-end and hop by hop options…) and requires specific optimizations.
- Buffer copies and locks are restricted to the very minimum and with the most efficient scheme (simple locks, read-write locks or Read-Copy-Update), or implementation method (transactional memory). For instance, table updates must be implemented to avoid any lock that would freeze the system.
- Layer 4 protocol (TCP/UDP) performance and latency are directly related to an efficient memory utilization and locking scheme because for each packet a socket has to be found and updated.
- High performance implies to manage a large number of network objects (interfaces, routing tables, filtering tables, security tunnels and associations…); efficient algorithms to parse large tables must be implemented.
- Hardware / software integration is critical to obtain high performance: location of data, use of caches, use of threads, communication between processors, and interface with PMD network drivers… must be optimized and require an in-depth knowledge of hardware capabilities.
- Adding protocols may have side effects and need a complete system test and validation.
- Stressing high performance software requires developing specific tools and environments to test software at different steps of the development.
- The validation of a new networking stack in carrier networks is a very long and costly process including proven interoperability.

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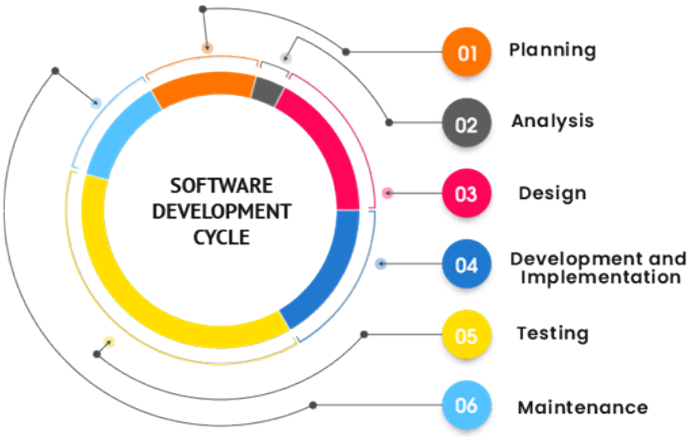

As a result, specifying, developing and testing high performance embedded data plane protocols is a very low-productivity software task even for skilled engineers.

Furthermore, as there are many technical challenges to solve when building up a networking stack, it's almost impossible to define the final software architecture without having proof of concept steps to select the right design options. Skipping this learning phase under the pressure of a tight development schedule significantly increases risks and may lead to major development slippage if software has to be partly or totally redesigned.

Impact on Software Environment

It's very important to design data plane protocols to avoid any impact on the software environment including control plane and management protocols, the Linux operating system, the hypervisor and DPDK. If the right architecture design rules are not well defined, the following major problems have to be solved:

- As new data plane software is developed, it requires APIs to be configured and monitored by both control plane (routing, security…) and management plane including NETCONF, SNMP, sFlow, NetFlow, etc., both running in userland. These APIs exist in a standard Linux environment and reusing them for the new data plane software avoids any modification to the control / management planes, otherwise control / management software has to be rewritten / revalidated and support may be broken.
- Data plane interacts with a large number of software components (Linux, KVM, QEMU, OpenStack…) that come from the open source community. If the data plane software requires patches to work with its environment, these patches must be proposed to the community. This process is unpredictable and requires allocating dedicated engineering resources that are familiar with the open source process. Sometimes patches that can be considered as too specific may not be accepted. In this case, these patches have to be ported, sometimes redesigned, and revalidated with each new version of the software and each version of the open source components.
- Unclear boundaries between the data plane software and open source environment may lead to potential issues with open source licenses like GPL. These issues can only be avoided by using a strict company-level process.
- Patching an environment that is supported by a commercial open source distribution provider generally terminates support contracts.

Even if the data plane software is designed to avoid any impact on its software environment, it must be validated with new versions of its environment. Commercially supported open source distributions can be used. In that case, data plane software will have to be validated with typical revision cycles of commercial releases.

Direct use of open source distributions leads to specific problems. Open source projects generally add new features to the latest released version. For instance, dpdk.org releases 3 or 4 versions a year. An internal process to use and support releases has to be defined to either always use the latest version or keep previous versions with some backports if features only available in new versions are required. Fixes done internally have to be provided to the community to be integrated in new versions to avoid additional backports.

This multiplies the maintenance effort to support the products in the field and those under development, which will likely use different open source distribution versions. The manpower tasked to this effort increases over time as more versions are deployed.

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Technology Evolutions

Multicore and NIC technologies evolve very fast, sometimes faster than their software development. Furthermore, deployment environments are moving towards full cloudification considerations (public clouds, VMs, Containers).

To benefit from the latest technology improvements that increase data plane software performance, packet processing software must be developed to be easily reused on different hardware architectures and different deployment environments. Clean hardware networking abstraction layers to fully leverage processor architectures and hardware accelerators have to be defined using standard packet handling services. Otherwise, software redesign and porting will be required to use different hardware architectures for a complete range of products and leverage technology improvements.

Networking and telco markets have fierce competition. Marketing teams want to differentiate products and drive for fast innovation. So, products must be enhanced quickly. For all these reasons, data plane software must evolve often with new features and protocols and requires a complete development and validation process. Of course, if the existing software has not been well designed, integrating new data plane features may have a significant impact in terms of development costs and time.

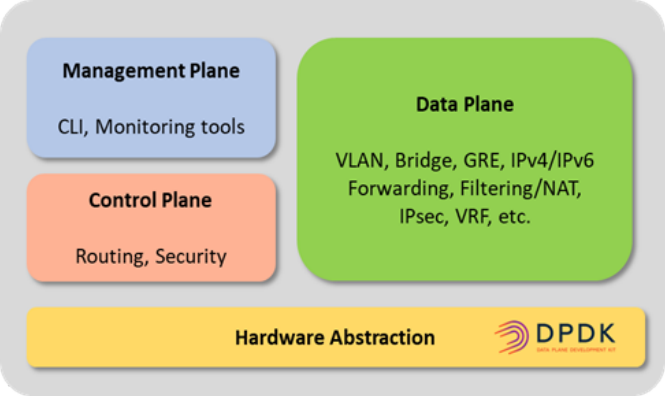
Other considerations

Like any other network software, the correct implementation of data plane protocols has to be checked through intensive integration, interoperability and vulnerability tests requiring high performance and very expensive testing equipment because data plane protocols process packets at a very high speed. Validation in real networks can be a long and expensive process for new network software implementations.

High Performance Networking Stack Example: “IPsec Security Gateway”

To illustrate all these different challenges, take the example of a security gateway. IPsec, for data plane, and IKE, for control plane, are the core protocols of a security gateway. However, the equipment has to implement a large number of additional Layer 2 and Layer 3 protocols to be integrated in complete network architecture. All these protocols have to be optimized, otherwise the overall performance of the equipment will be very poor.

IPsec itself is a very complex protocol with a large number of options including support for IPv4, IPv6 and many encapsulation mechanisms. IPsec crypto algorithms consume a lot of processing bandwidth that may require hardware accelerators to offload the main processor. Keeping a common interface to use either software crypto libraries or hardware accelerators is a very important requirement to develop a range of products.



High performance security gateways have to manage a very large number of security policies and associations. Standard implementations of IPsec and IKE cannot scale to address this requirement. Keeping standard interfaces between IKE and IPsec is a key requirement to avoid redesigning the IKE control plane protocol.

Finally, managing security policies is a very important feature and high-level configuration tools are required to automate policy configuration and interfaces with key or certificate management systems.

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A complete IPsec security gateway based on Intel / DPDK architecture should at least implement the following protocols:

DPDK

- DPDK with required PMD NIC drivers
- Crypto software libraries and crypto accelerator support (Intel Cave Creek, Cavium Nitrox…)
- Virtio guest DPDK driver if the security gateway runs in a Virtual Machine

Data Plane Protocols

- VLAN, VxLAN
- Link Aggregation
- Ethernet Bridge
- IPv4 / IPv6 Forwarding
- IPsec v4 and IPsec v6
- IPv4 / IPv6 Reassembly
- IPv4 / IPv6 Filtering
- Virtual Routing and Forwarding
- Tunneling (IP in IP, GRE…)
- QoS
- Flow Inspection / Packet Capture (for debugging)

Control Plane Protocols

- Synchronization between Linux and data plane protocols to easily reuse standard control plane protocols
- Routing including virtual routing
- IKE
- LACP

Management

- CLI, NETCONF, SNMP, Sflow, KPIs, …
- Interface with key or certificate management systems

High availability

- Active/backup redundancy with Hot Standby capabilities:
  - Synchronization of Security Associations
  - Synchronization of Sequence Numbers

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Comparing In-house vs. 6WINDGate-based Development

In this section we will review the challenges to be solved to develop this kind of software.

6WINDGate is a fast path–based data plane networking stack that has been specifically designed to extract the highest performance for packet processing on multicore platforms. Beyond pure performance, 6WINDGate includes all the required features to provide a long-term, ready-to-use solution to minimize development costs and reduce time to market:

- **Optimized software architecture** that linearly scales over a large number of cores located in a single processor or in different processors to deliver unequalled packet processing performance.
- **Complete modular Layer 2 – Layer 4 networking stack** optimizing all IP protocols; customers can purchase the exact list of modules required for their applications and add new modules to provide more services in further steps.
- **Transparent solution for the software environment.** Running Linux and 6WINDGate is identical to running Linux. 6WINDGate's fast path is completely hidden to applications thanks to its continuous synchronization with Linux. So, Linux applications, including management frameworks, work unmodified with 6WINDGate. Using 6WINDGate doesn't require any patching, in the Linux kernel, the hypervisor, or management framework. Customers can keep their standard commercial support agreements in place.
- **Advanced Management and Monitoring with APIs.** 6WINDGate provides both traditional, CLI-based management and management based on YANG and NETCONF APIs for integration with higher level orchestrators and management frameworks. For monitoring, besides the traditional SNMP and syslog mechanisms, data plane sampling through sFlow, and streaming telemetry with time series data base and graphical analytics are supported.
- **Availability on all market-leading multicore platforms.** More than 90% of the 6WINDGate dataplane software is written in standard C code and can be reused as is on the networking hardware abstraction layer developed by 6WIND on top of the processor SDKs. The 6WIND DPDK commercial distribution also supports a large number of NICs and crypto accelerators from several providers. Using 6WINDGate guarantees fast porting on new hardware architectures and minimizes support costs in case a customer uses 6WINDGate on different hardware platforms to develop a complete range of products.
- **6WINDGate is a proven solution.** Since its first shipment in 2007, it has been deployed in production in critical carrier network equipment and has been in operation for years showing its quality, interoperability and scalability.

For the complete set of data plane protocols listed in the previous section that are required for a security gateway, the estimated in-house development workload, staring from ground-up, to release a first version of the security gateway equipment based on a generic bare-metal Intel server using DPDK is estimated at **200 man months (8 engineers during a period of 25 months).** This estimation assumes the work is done by a team of skilled networking software developers (refer to “Development Requirements Task List” section) and does not include any skills ramp up period nor any additional workload linked to possible software redesign needs.

In comparison the estimated workload to integrate 6WINDGate for a first version of the same equipment is **15man months (3 engineers during 5 months)** and requires more standard software integration skills.

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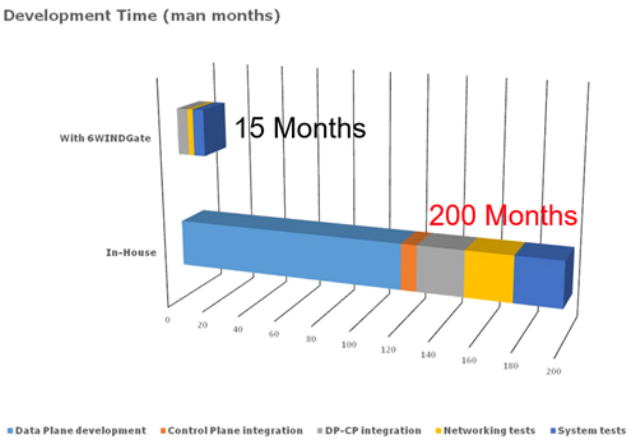
Development Requirements Task List

- Build Team
- Develop optimized data protocols
- Bare metal and virtualization support
- Linux Integration
- Monitoring (SNMP, KPIs, NetFlow)
- Create Control Plane API
- Integration with Control Plane and Management Plane
- CLI, XML, key/certificate management
- Testing (Performance, vulnerability)
- Validation in real networks
- Maintenance
- Validation with new versions of the software environment
- Development of additional features to differentiate products
- Portability

The following diagram details the engineering workload for the two options in the different phases of the project. It's assumed the in-house development uses third party or in-house control plane protocols (including management) that are not to be redeveloped but only integrated with the high-performance data plane. Networking tests include performance and interoperability tests. Maintenance, validation with evolutions of software environment (DPDK, Linux...) are not included.



6WINDGate also delivers long-term benefits including:

- Availability on different hardware platforms to avoid vendor lock-in
- Virtualization ready solution to accelerate the evolution to virtualized appliances for deployments in private and public clouds based on either KVM, VMWare, AWS or Azure.
- Support of containers deployments (docker, Kubernetes)
- Extensible Netconf/Yang based Management plane (CLI, Yang models, KPIs).
- Simple development of added value features thanks to Linux transparency
- Extensibility with new protocols when required
- Validation with major software distributions (Linux, hypervisor, OpenStack)
- 6WIND roadmap

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Conclusion

Developing high performance embedded data plane software requires very specific networking and software skills. Specifying, developing and testing this kind of software is a very low-productivity software task.

Considering the extreme complexity of the software to be developed for the current generation of networking and telecom equipment, product line and software team managers should carefully analyze the potential risk as underestimating the complexity may lead to software development hell, unexpected extra development costs and significant delivery delays.

6WINDGate is the result of more than 350 man-years of software R&D and deep expertise in networking.

Using 6WINDGate significantly reduces development risk to keep develop costs under control, ship products on time and quickly generate revenues. 6WINDGate's architecture is a valuable long-term investment to easily benefit from the latest improvements of processors, NIC technologies, network protocols and multi-environments deployment capabilities (bare metal, VMs and docker containers).