

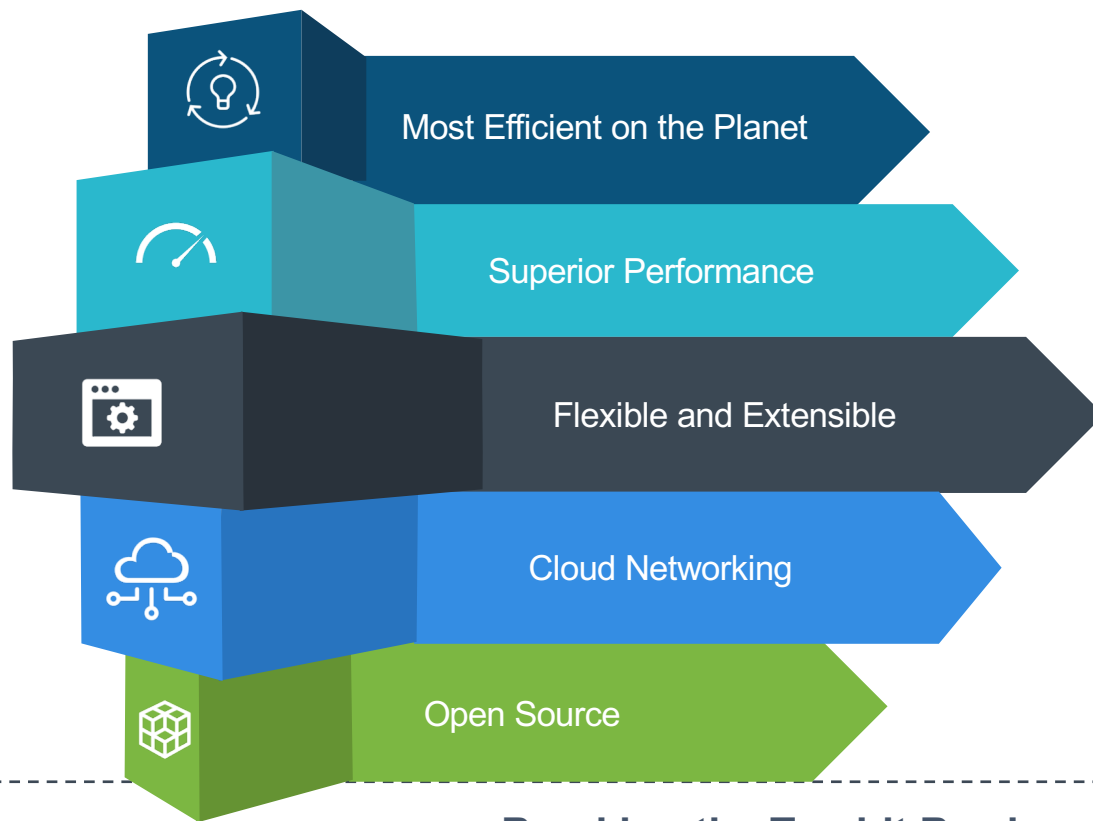
A *Terabit* Secure Network Data-Plane

Software for Breaking the Barriers: 1 Tb/s, 1 Bpkts/s, ...



A Terabit Secure Network Data-Plane

For Cloud Network Services



EFFICIENCY

The most efficient software data plane Packet Processing on the planet



PERFORMANCE

FD.io on x86 servers outperforms specialized packet processing HW



SOFTWARE NETWORKING

Software programmable, extendable and flexible



CLOUD NETWORK SERVICES

Foundation for cloud network services



LINUX FOUNDATION

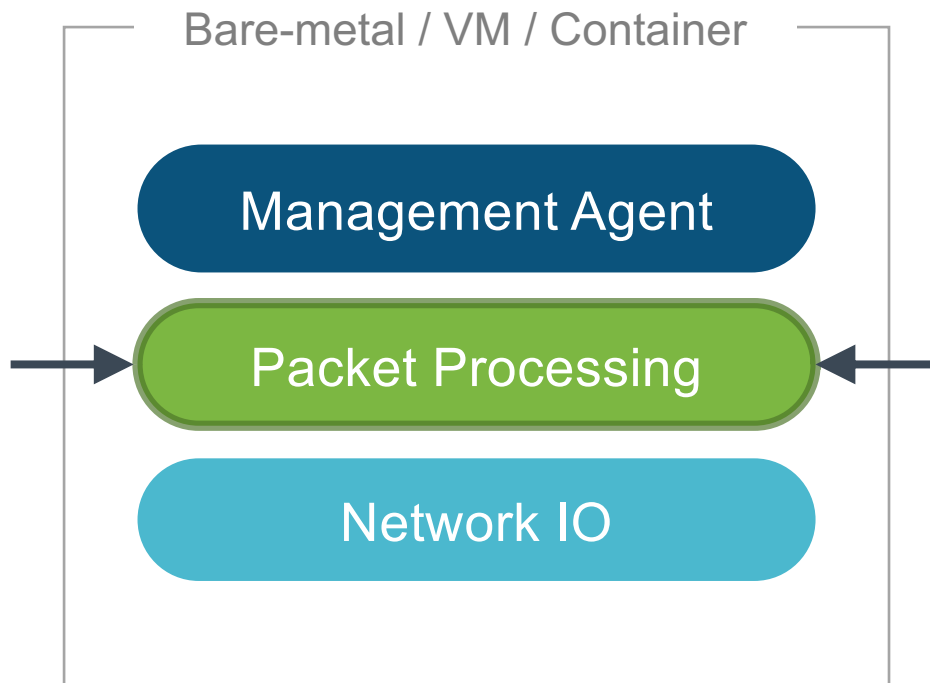
Open source collaborative project in Linux Foundation






**Breaking the Terabit Barrier of Secure NaaS Services
on a Single 2-Socket Intel® Xeon® Server !**

FD.io VPP – Vector Packet Processor

Compute Optimized SW Network Platform



Packet Processing Software Platform

- High performance
- Linux user space
- Runs on compute CPUs:   
 - And “knows” how to run them well !

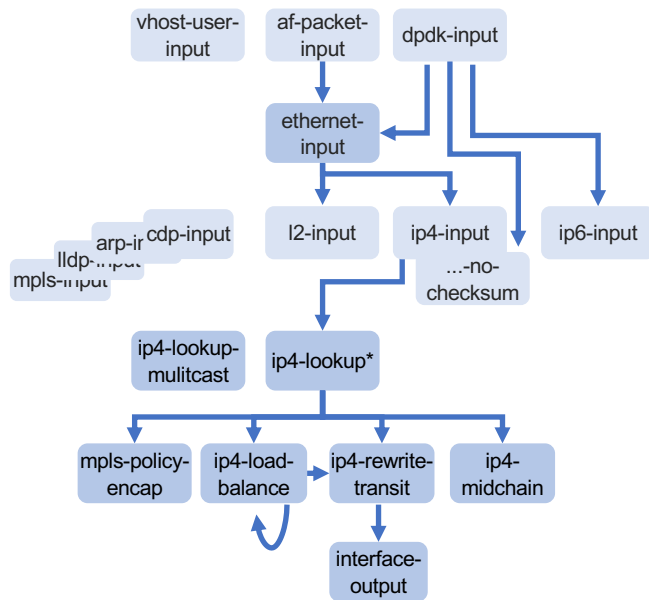
Shipping at volume in server & embedded products since 2004



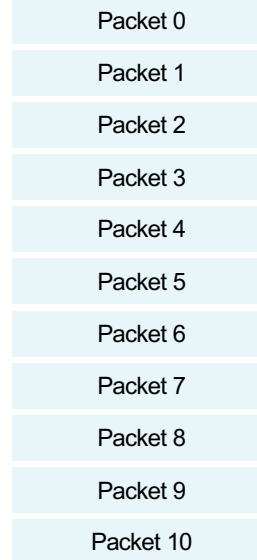
FD.io VPP – The “Magic” of Vectors

Compute Optimized SW Network Platform

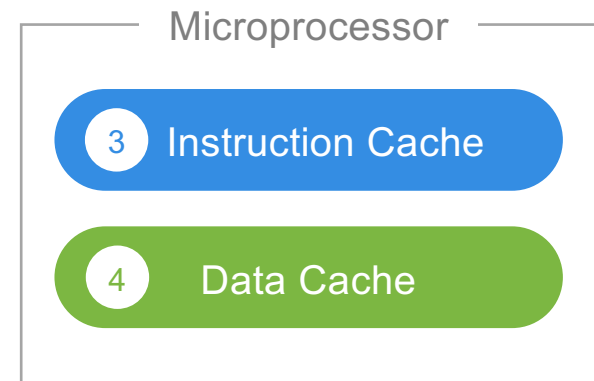
1 Packet processing is decomposed into a directed graph of nodes ...



2 ... packets move through graph nodes in vector ...



3 ... graph nodes are optimized to fit inside the instruction cache ...



4 ... packets are pre-fetched into the data cache.

* Each graph node implements a “micro-NF”, a “micro-NetworkFunction” processing packets.



Makes use of modern Intel® Xeon® Processor micro-architectures.
Instruction cache & data cache always hot → Minimized memory latency and usage.

FD.io Benefits from Intel® Xeon® Processor Developments

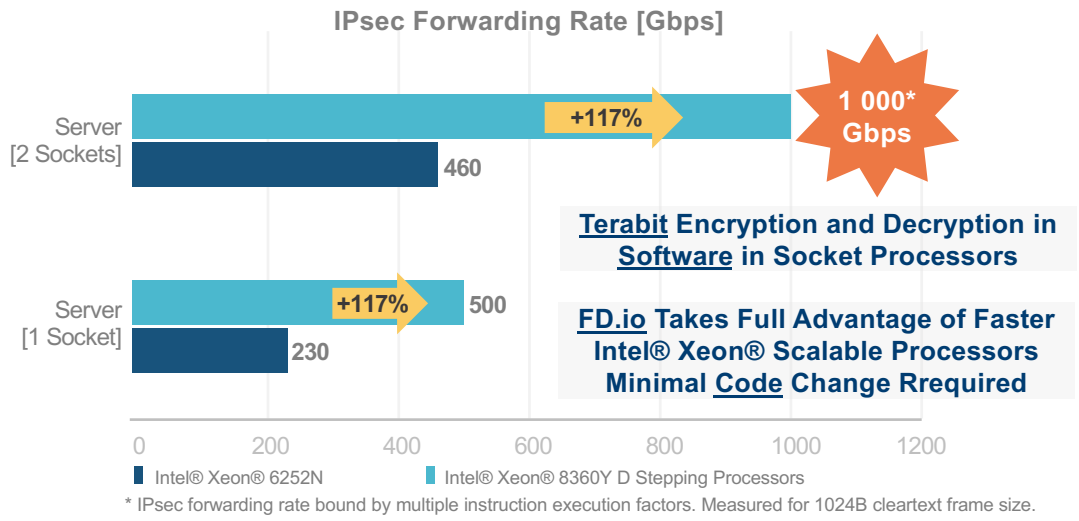
Increased I/O and Cipher Processing Improve Crypto Throughput

FD.io = Terabit NaaS
Intel® Xeon®

YESTERDAY

- 1 Network I/O PCIe Gen3: **320 Gbps**
- 2 Per Core Caches: L1d **32 KB**, L2 **1.0 MB**
- 3 Memory: **6-channels** 2666 MHz
- 4 Max power: **150 W (TDP)**

Intel® Xeon® 6252N
24 Cores, 2.3 GHz, 33 MB Cache



TODAY

- 1 Network I/O PCIe Gen4: **600 Gbps**
- 2 Per Core Caches: L1d **48 KB**, L2 **1.25 MB**
- 3 Memory: **8-channels** 3200 MHz
- 4 Max power: **250 W (TDP)**

Intel® Xeon® 8360Y D Stepping
36 Cores, 2.4 GHz, 54 MB Cache



Breaking the Terabit Barrier of Secure NaaS Services on a Single 2-Socket Intel® Xeon® Server !



FD.io Benefits from Intel® Xeon® Processor Developments

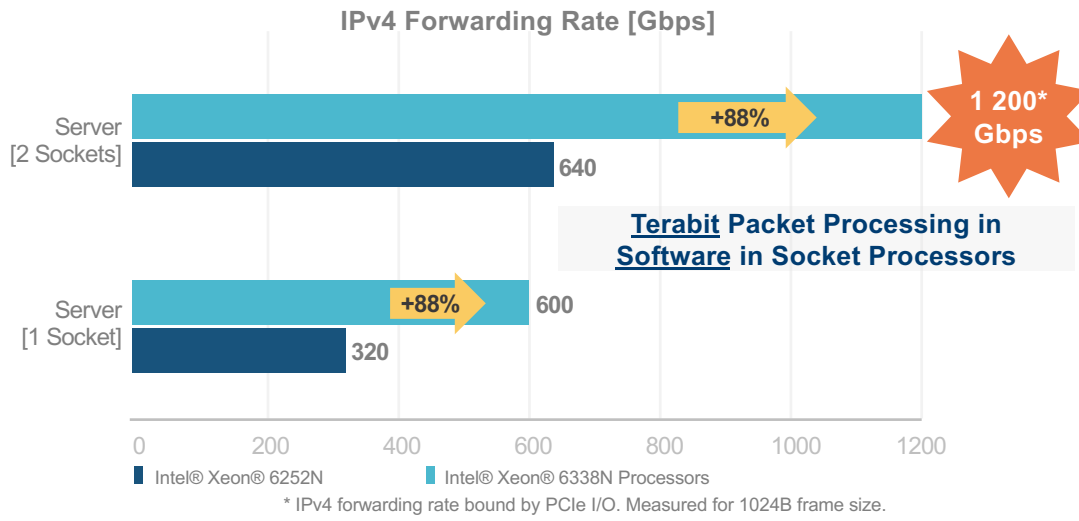
Increased I/O and Processing Power Improve Packet Throughput

FD.io
Intel® Xeon® = Terabit NaaS

YESTERDAY

- 1 Network I/O PCIe Gen3: **320 Gbps**
- 2 Per Core Caches: L1d **32 KB**, L2 **1.0 MB**
- 3 Memory: **6-channels** 2666 MHz
- 4 Max power: **150 W (TDP)**

Intel® Xeon® 6252N
24 Cores, 2.3 GHz, 33 MB Cache



TODAY

- 1 Network I/O PCIe Gen4: **600 Gbps**
- 2 Per Core Caches: L1d **48 KB**, L2 **1.25 MB**
- 3 Memory: **8-channels** 3200 MHz
- 4 Max power: **185 W (TDP)**

Intel® Xeon® 6338N
32 Cores, 2.2 GHz, 42 MB Cache



Breaking the Terabit Barrier of Secure NaaS Services on a Single 2-Socket Intel® Xeon® Server !



FD.io VPP & Cloud Network Services

Use Case Examples

FD.io
Intel® Xeon® = Terabit NaaS



SECURE NaaS CLOUD NETWORKING

Encrypted Overlays for Secure Access, Edge and Connectivity

- IPsec, TLS, QUIC, WireGuard - Fast Modern VPNs
- Horizontal Scaling with Near Linear Multi-core Speed-up
- Secure Tunnels: 40 Gbps / Core, up to 1 Tbps / 2 Sockets

Scale of Million Routes with Service Features

- Performance at Max. of PCIe I/O of Intel® Xeon® Server



MULTI-TENANT SERVICES

Per Tenant Stateless and Stateful Packet Processing

- Rich IPv4/IPv6 Functionalities, API First Consumption Model
- Zero Cost Telemetry with Always-on Pervasive Data-plane Counters
- Service Features: ACLs, NAT, Sessions, VRFs

Multi-Tenant Scale and Elasticity

- Scale of Million Flows with Service Features



Substantial Performance and Efficiency Gains vs. Alternatives



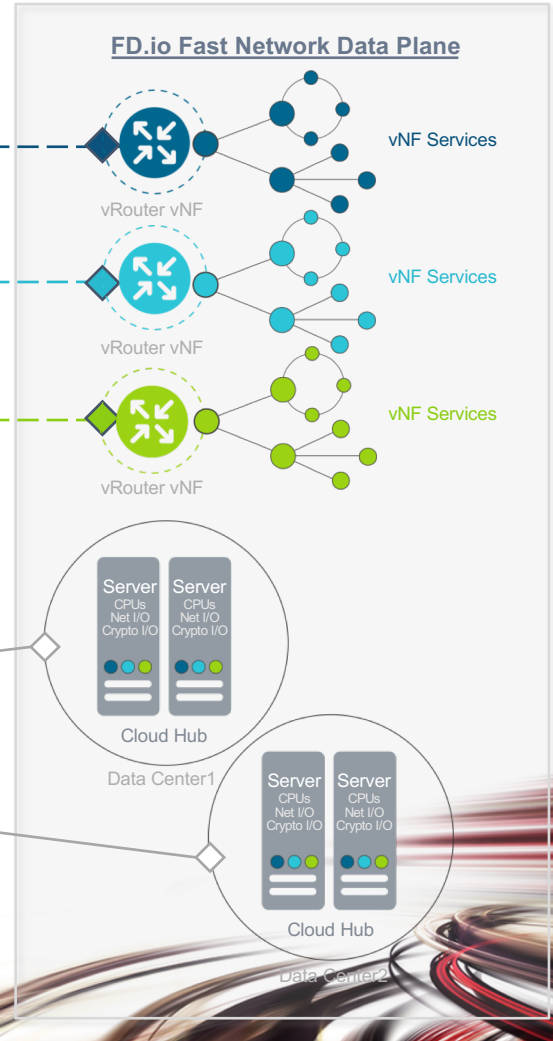
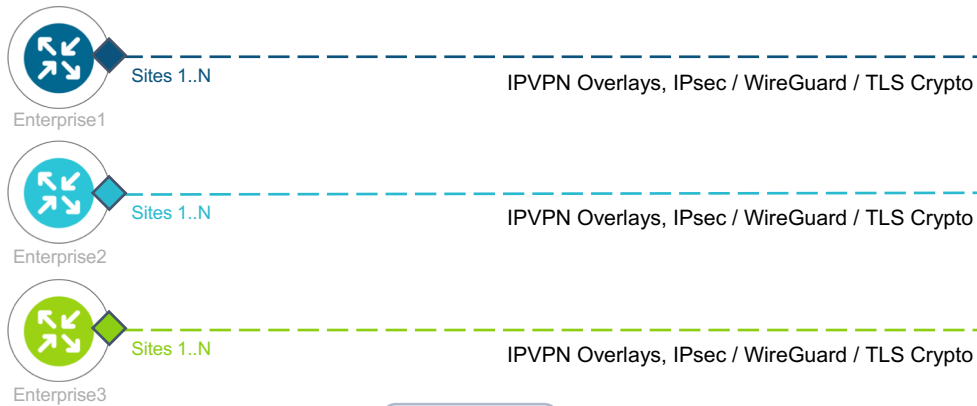
Fast Cloud Network Services

With Terabit Secure Network Data Plane

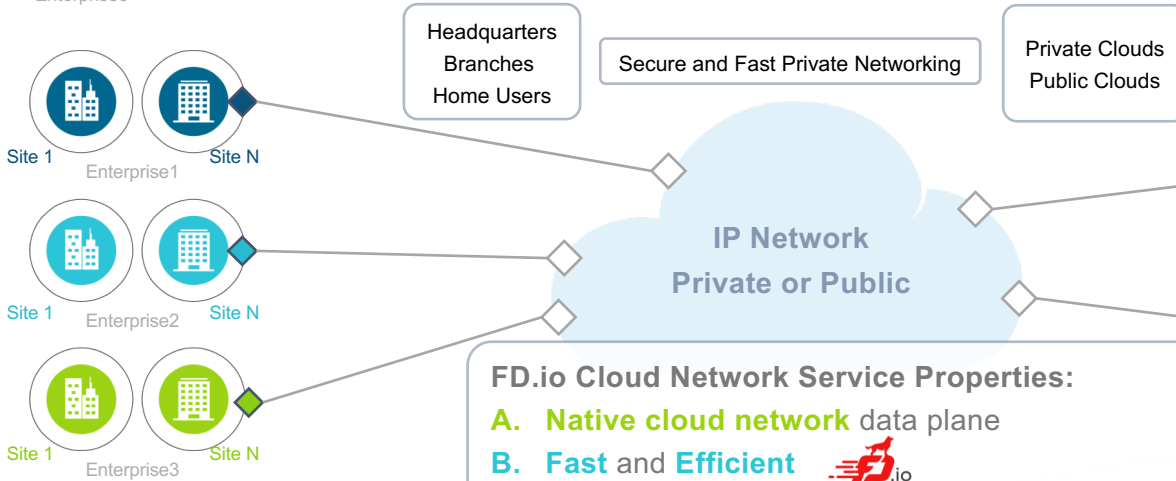
FD.io
Intel® Xeon® = Terabit NaaS

Network-as-a-Service – IPVPN, Internet Security, SASE Offerings

SERVICE VIEW



PHYSICAL VIEW



- FD.io Cloud Network Service Properties:**
- A. Native cloud network data plane
 - B. Fast and Efficient
 - C. ~1,000 Gbps IPsec per 2 socket Intel® Xeon® server



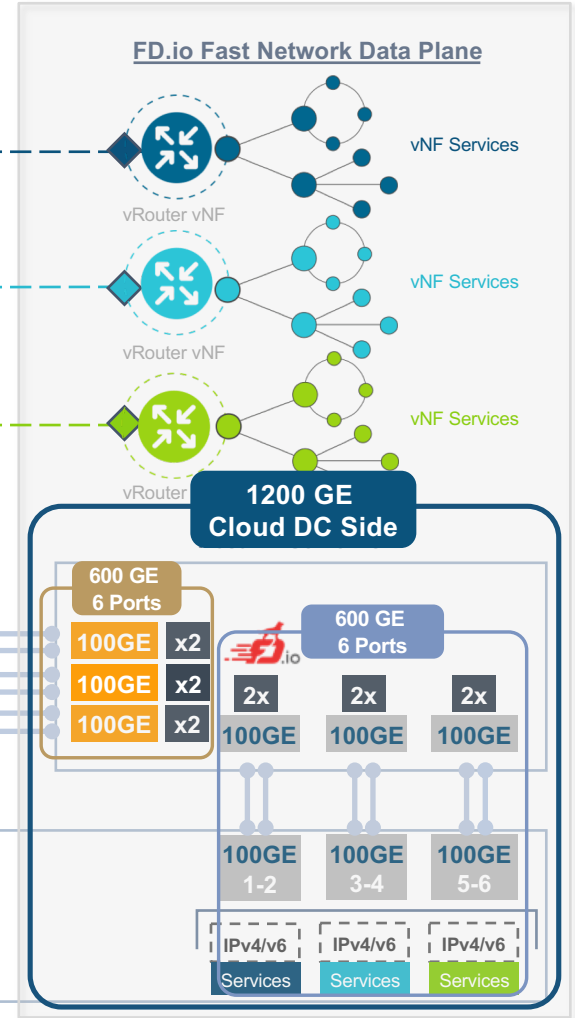
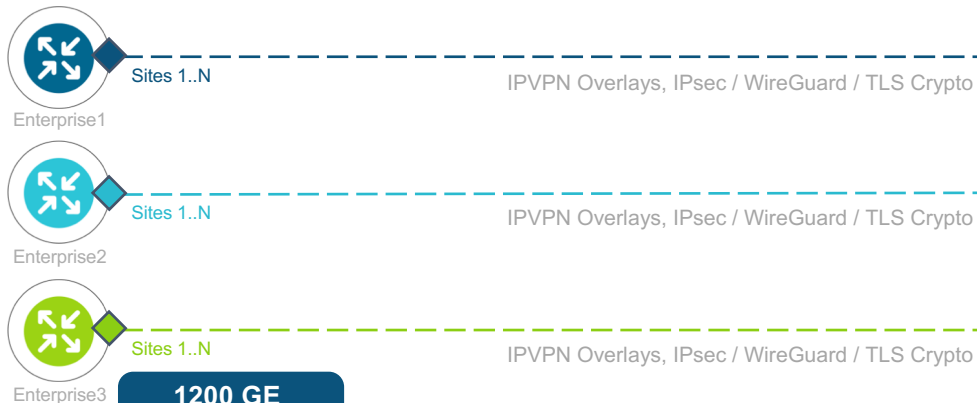
Fast Cloud Network Services

With Terabit Secure Network Data Plane

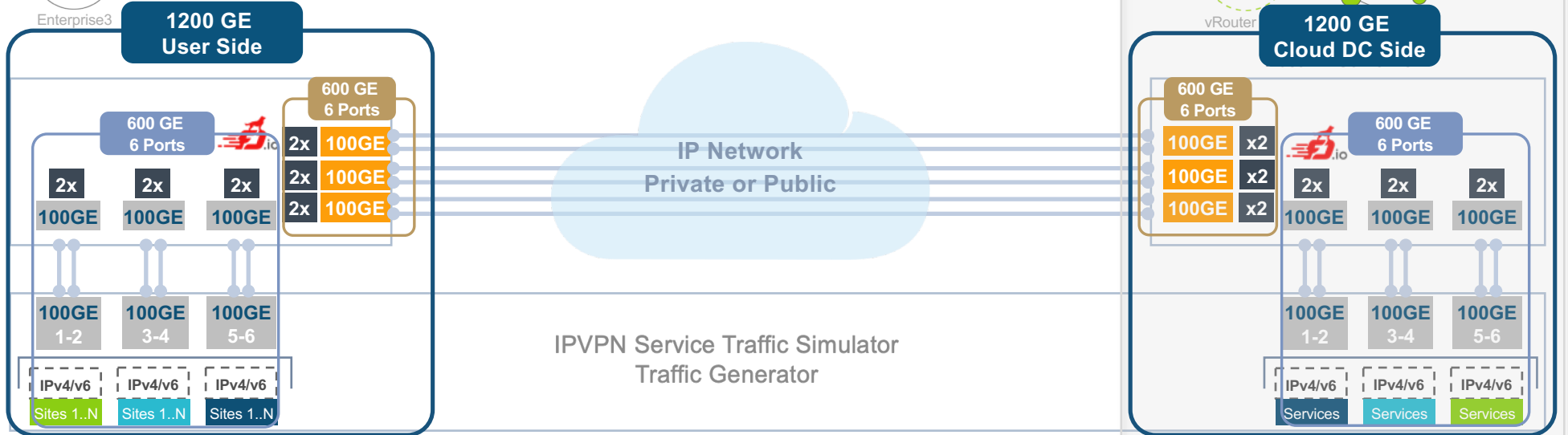
FD.io
Intel® Xeon® = Terabit NaaS

Network-as-a-Service – IPVPN, Internet Security, SASE Offerings

SERVICE VIEW



PHYSICAL VIEW



Fast Cloud Network Services - IPsec

FD.io
Intel® Xeon® = Terabit NaaS

With Tera

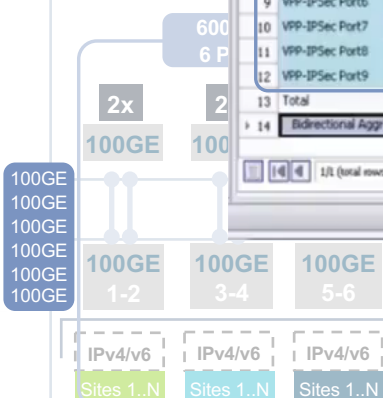
Enabled	Transit State	Suspend	Tx Port	Rx Ports	Flow Group Name	Configured Frame Size	Applied Frame Size	Frame Rate	Tx port type
✓	🟢	🔴	VPP-IPSec Port1	VPP-IPSec Port2;	VPP-IPSec-EndpointSet-1 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port2	VPP-IPSec Port1;	VPP-IPSec-EndpointSet-2 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port3	VPP-IPSec Port4;	VPP-IPSec-EndpointSet-3 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port4	VPP-IPSec Port3;	VPP-IPSec-EndpointSet-4 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port5	VPP-IPSec Port6;	VPP-IPSec-EndpointSet-5 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port6	VPP-IPSec Port5;	VPP-IPSec-EndpointSet-6 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port7	VPP-IPSec Port8;	VPP-IPSec-EndpointSet-7 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port8	VPP-IPSec Port7;	VPP-IPSec-EndpointSet-8 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port9	VPP-IPSec Port10;	VPP-IPSec-EndpointSet-9 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port10	VPP-IPSec Port9;	VPP-IPSec-EndpointSet-10 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port11	VPP-IPSec Port12;	VPP-IPSec-EndpointSet-11 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet
✓	🟢	🔴	VPP-IPSec Port12	VPP-IPSec Port11;	VPP-IPSec-EndpointSet-12 ...	Fixed: 1024	Fixed: 1024	65% Line Rate	Ethernet

Tx Port	Rx Port	Traffic Item	Flow Group	Tx Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Tx L1 Rate (bps)	Rx L1 Rate (bps)
1 VPP-IPSec Port1	VPP-IPSec Port2	VPP-IPSec	VPP-IPSec-EndpointSet-1 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
2 VPP-IPSec Port10	VPP-IPSec Port9	VPP-IPSec	VPP-IPSec-EndpointSet-10 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
3 VPP-IPSec Port11	VPP-IPSec Port12	VPP-IPSec	VPP-IPSec-EndpointSet-11 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
4 VPP-IPSec Port12	VPP-IPSec Port11	VPP-IPSec	VPP-IPSec-EndpointSet-12 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
5 VPP-IPSec Port2	VPP-IPSec Port1	VPP-IPSec	VPP-IPSec-EndpointSet-2 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
6 VPP-IPSec Port3	VPP-IPSec Port4	VPP-IPSec	VPP-IPSec-EndpointSet-3 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
7 VPP-IPSec Port4	VPP-IPSec Port3	VPP-IPSec	VPP-IPSec-EndpointSet-4 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
8 VPP-IPSec Port5	VPP-IPSec Port6	VPP-IPSec	VPP-IPSec-EndpointSet-5 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
9 VPP-IPSec Port6	VPP-IPSec Port5	VPP-IPSec	VPP-IPSec-EndpointSet-6 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
10 VPP-IPSec Port7	VPP-IPSec Port8	VPP-IPSec	VPP-IPSec-EndpointSet-7 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
11 VPP-IPSec Port8	VPP-IPSec Port7	VPP-IPSec	VPP-IPSec-EndpointSet-8 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
12 VPP-IPSec Port9	VPP-IPSec Port10	VPP-IPSec	VPP-IPSec-EndpointSet-9 - Flow Group 0001	0	0	0	0	0.000	0.000	0.000	0.000
13 Total				0	0	0	0	0.000	0.000	0.000	0.000
14 Bidirectional Aggregate								Aggr. Frame Rate =	0.000	Aggr. L1 Rate (bps) =	0.000

SERVICE VIEW



PHYSICAL VIEW



1 Terabit/s IPsec
cleartext 1024B frame size **AES128GCM**

Data Plane

vNF Services

vNF Services

vNF Services

CX

GE ports

GE

GE

Services

Services

Services



Fast Cloud Network Services – IPv4

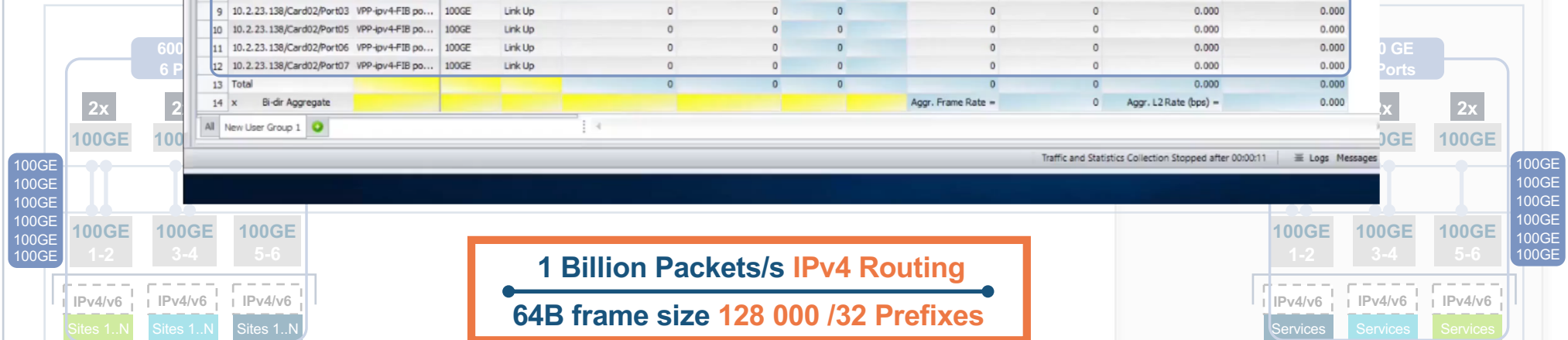
FD.io
Intel® Xeon® = Terabit NaaS

With Tera

SERVICE VIEW



PHYSICAL VIEW



Enabled	Transmit State	Suspend	Tx Port	Rx Ports	Flow Group Name	Encapsulation Editor	Configured Frame Size	Applied Frame Size	Frame Rate	Preamble Size	CRC
Traffic Item Name: VPP-forwarding TX Mode: Interleaved, Src/Dst Mesh: OneToOne, Route Mesh: OneToOne, Uni-directional											
13	✓	✓	VPP-ipv4-FIB port 1	VPP-ipv4-FIB port 2;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
14	✓	✓	VPP-ipv4-FIB port 2	VPP-ipv4-FIB port 1;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
15	✓	✓	VPP-ipv4-FIB port 3	VPP-ipv4-FIB port 4;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
16	✓	✓	VPP-ipv4-FIB port 4	VPP-ipv4-FIB port 3;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
17	✓	✓	VPP-ipv4-FIB port 5	VPP-ipv4-FIB port 6;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
18	✓	✓	VPP-ipv4-FIB port 6	VPP-ipv4-FIB port 5;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
19	✓	✓	VPP-ipv4-FIB port 7	VPP-ipv4-FIB port 8;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
20	✓	✓	VPP-ipv4-FIB port 8	VPP-ipv4-FIB port 7;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
21	✓	✓	VPP-ipv4-FIB port 9	VPP-ipv4-FIB port 10;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
22	✓	✓	VPP-ipv4-FIB port 10	VPP-ipv4-FIB port 9;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
23	✓	✓	VPP-ipv4-FIB port 11	VPP-ipv4-FIB port 12;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error
24	✓	✓	VPP-ipv4-FIB port 12	VPP-ipv4-FIB port 11;	VPP ipv4 FIB 4k flows - Flo...	Ethernet II.IPv4	Fixed: 64	Fixed: 64	83335333 fps	Auto	No Error

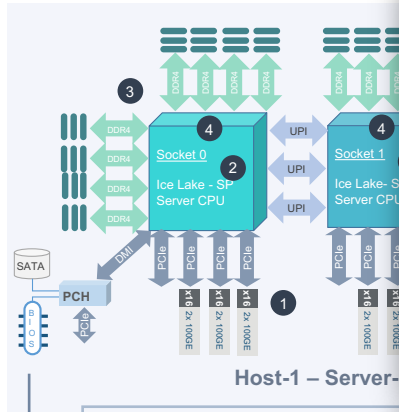
Stat Name	Port Name	Line Speed	Link State	Frames Tx.	Valid Frames Rx.	Frames Delta	Loss (%)	Frames Tx. Rate	Valid Frames Rx. Rate	Tx. Rate (bps)	Rx. Rate (bps)
1	10.2.23.138/Card01/Port03	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
2	10.2.23.138/Card01/Port04	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
3	10.2.23.138/Card01/Port05	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
4	10.2.23.138/Card01/Port06	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
5	10.2.23.138/Card01/Port07	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
6	10.2.23.138/Card01/Port08	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
7	10.2.23.138/Card02/Port01	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
8	10.2.23.138/Card02/Port02	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
9	10.2.23.138/Card02/Port03	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
10	10.2.23.138/Card02/Port05	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
11	10.2.23.138/Card02/Port06	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
12	10.2.23.138/Card02/Port07	100GE	Link Up	0	0	0	0	0	0	0.000	0.000
13	Total			0	0	0	0	0	0	0.000	0.000
14	x Bi-dir Aggregate							Aggr. Frame Rate =		Aggr. L2 Rate (bps) =	0.000

1 Billion Packets/s IPv4 Routing
64B frame size 128 000 /32 Prefixes

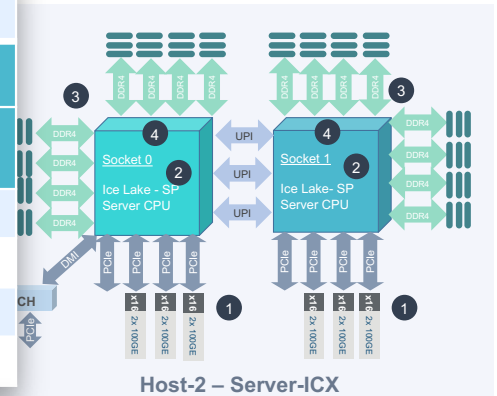


FD.io VPP – The “Magic” Behind the Equation

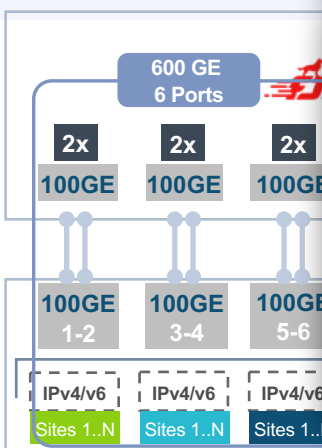
FD.io
Intel® Xeon® = Terabit NaaS



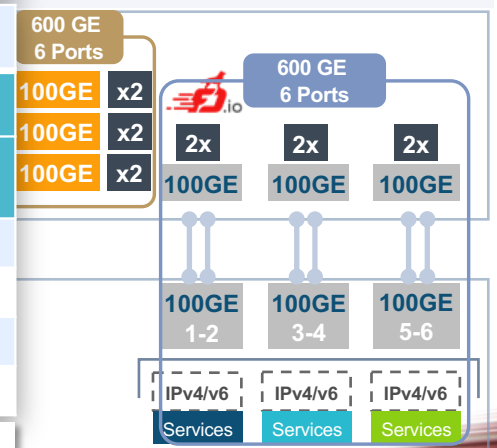
IPsec Encryption and Decryption			
FD.io Data Plane Efficiency Metrics: { + } higher is better { - } lower is better	YESTERDAY	TODAY	
	Intel® Xeon® 6252N	Intel® Xeon® 8360Y D stp	Improvement
{ + } 2 Socket forwarding rate [Gbps]	460 Gbps	1000 Gbps	+117 %
{ - } Cycles / Packet	1147	612	-47 %
{ + } Instructions / Cycle	2.89	2.96	+2 %
{ - } Instructions / Packet	3313	1815	-45 %



PHYSICAL VIEW



IPv4 Routing			
FD.io Data Plane Efficiency Metrics: { + } higher is better { - } lower is better	YESTERDAY	TODAY	
	Intel® Xeon® 6252N	Intel® Xeon® 6338N	Improvement
{ + } 2 Socket forwarding rate [Gbps]	640 Gbps	1200 Gbps*	+88 %
{ - } Cycles / Packet	139	124	-11 %
{ + } Instructions / Cycle	2.90	3.29	+13 %
{ - } Instructions / Packet	405	409	+1 %



* Measured 2 Socket forwarding rate is limited by PCIe I/O slot layout on tested compute machines; nominal forwarding rate for tested FD.io VPP configuration is 600 Gbps per Processor. Not all cores are used.



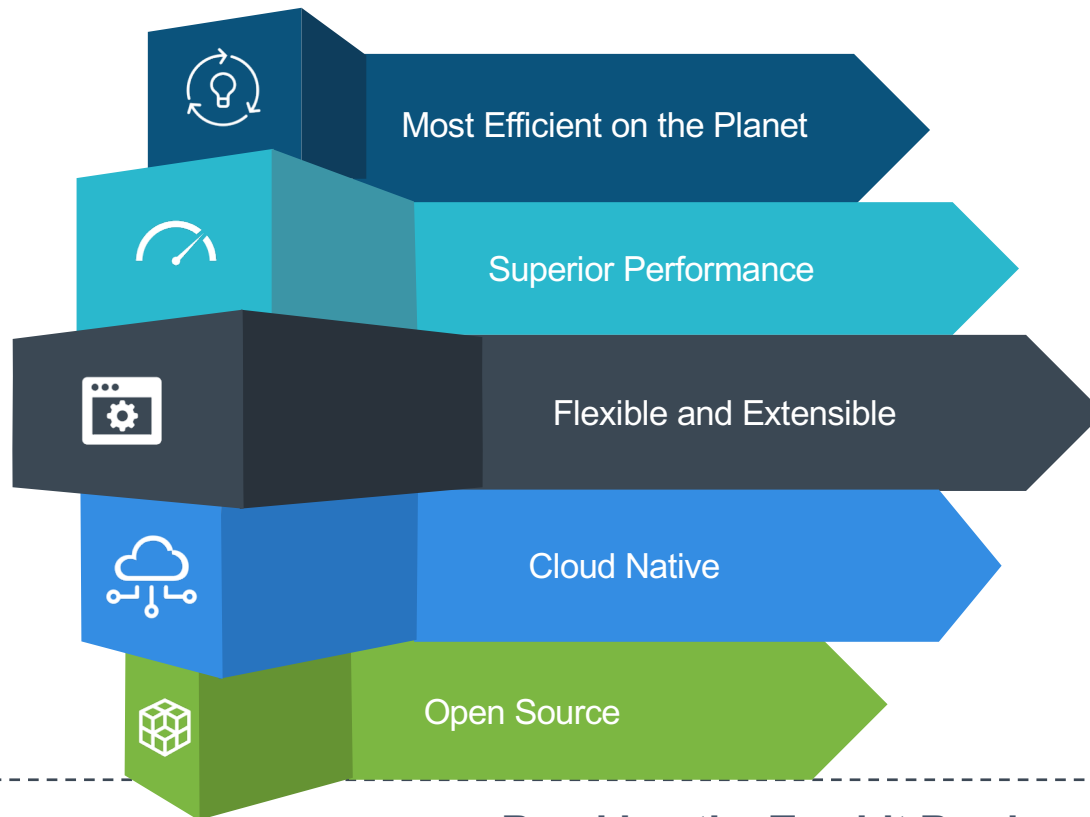
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A Terabit Secure Network Data-Plane

For Native Cloud Network Services

FD.io
Intel® Xeon® = Terabit NaaS



EFFICIENCY

Now even less CPU core cycles per packet: IPsec from 1147 to 612, IPv4 from 139 to 124



PERFORMANCE

Best-in-class performance metrics, Terabit rates with IPsec, Billion packets/sec with IPv4 at Scale



SOFTWARE NETWORKING

Many programmable NF graph nodes, ~20 extension NF plugins, maximizing flexibility



CLOUD NETWORK SERVICES

User-space data plane with optimized SW / HW interface for high density cloud native micro-services



LINUX FOUNDATION

FD.io collaboration activity: 21k+ commits, 500+ contributors, 120+ organizations



Breaking the Terabit Barrier of Secure NaaS Services
on a Single 2-Socket Intel® Xeon® Server !

