An Overview of Cloud-Native Networks Design and Testing

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Outline

• Background on Cloud-Native & Cloud-Native Networks
• Open Source Landscape
• Performance Challenges and Acceleration Techniques
• Testing and Observability
• Design Principles
• Takeaways
What’s Cloud Native?

- Combination of Containers, CI/CD, Microservices, Declarative APIs, DevOps
- Key benefits
  - Ship fast, reduce risk
  - Scalability, Agility, Resiliency
- Cloud technologies evolution timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Amazon EC2</td>
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<tr>
<td>2010</td>
<td>Netflix Cloud Migration</td>
</tr>
<tr>
<td>2015</td>
<td>Kubernetes CNCF</td>
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<tr>
<td>2018</td>
<td>CNFs Definition ONAP containerization</td>
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Cloud-Native Networks

• Deliver networking in a cloud env; Network itself is implemented with cloud-native principles
• Kubernetes as container orchestrator; Networking via container networking interface (CNI) plugins; Linux kernel as the building blocks
• Cloud-Native Networks basic functions
  • General Pod connectivity
  • IP address management (IPAM)
  • Service handling and load balancing
  • Network policy enforcement
  • Monitoring and troubleshooting
Cloud-Native Networks in Kubernetes

- Basic Kubernetes networking definitions
  - Pod: a group of containers on a same host, IP per Pod, change dynamically
  - Service: a group of endpoints (pods), stable virtual IP
  - Flat network inside cluster, all Pods can communicate without NAT
  - Plugin-based network solution, create networks for pods when Kubernetes initiate Pods
  - Network policy describe the allowed communication among Pods
  - 4 types communication: container-to-container, Pod-to-Pod, Pod-to-Service, External-to-Service

Bridge Plugin Example
1. Create bridge network
2. Create a veth pair
3. Attach one veth to Pod namespace
4. Attach the other veth to bridge
5. Assign IP address
6. Bring interface up
7. Enable NAT

$ bridge add <CID> <Namespace>
Open Source Landscape – CNCF Cloud-Native Networks

- A view of 23 cards, market cap of $561.87B and funding of $393.8M*

*https://landscape.cncf.io/
Problems Covered

- Container Network Interface Standards
- Generic Solutions
- Multiple interfaces in a container
- Data plane acceleration
- Hardware acceleration
- Multi-cloud networking
Performance Challenges

- **Linux networking stack issues**
  - Complex, ~12 millions lines of code
  - A copy is needed from user space to kernel space
  - Packet flow is long, especially with NetFilter (port mapping, NAT, etc)

Kernel Networking Stack

NetFilter packet flow (5 chains, 5 tables)
Software Acceleration Technologies

- Software-based, provide fast-path for packets, utilize unique CPU features
  - DPDK/VPP, user space forwarding, bypass kernel
  - eBPF, customize kernel packet processing flow, maximize efficiency

![Diagram of software acceleration technologies](image)
eBPF (extended Berkeley Packet Filter)*

- “Superpower”, reprogram the behavior of Linux kernel without changing source code
- Component: eBPF program and Maps, Hooks, Helper functions
- Toolchains: bcc, bpftrace, go/c/c++ lib
- Applications, run eBPF program on events
  - Networking, Security, Tracing & Profiling, Observability & Monitoring
- Industry adoption
  - Cilium (eBPF-based CNI), Cloudflare (eBPF-based DDos)
  - Facebook, L3-L4 load balancing, network security, profiling, etc.
  - Google, Cilium & eBPF as the new networking data plane for GKE

*https://ebpf.io/what-is-ebpf
Hardware Acceleration Technologies

- Utilize different processing architecture (SmartNIC, FPGA, GPU) to parse and dispatch network packets instead of CPU
  - Network throughput greatly increased, but not the CPU computation power
- Offload network functions to hardware
  - TCP, TLS/IPsec crypto, OVS*
- Adoption is driven by hyperscalers
  - Azure, FPGA-based SmartNIC, programmed using generic flow tables
  - GCP, GPU attached VM, throughput is up to 100 Gbps
  - AWS, Nitro card

*https://antrea.io/presentations/
Testing Infrastructure

- CI/CD pipeline, from source to production ASAP

- CI/CD Tools
  - Trigger/schedule tests/tasks; Manage source/artifact/results
  - CNCF has 30+ projects
Test Cases

• Functional Tests
  • Connectivity Test (readiness, liveness)
  • Policy Test (firewall rules)

• Performance Tests
  • Function itself (latency/throughput)
  • Function at scale (large no. of requests/nodes, large tables/database)
Performance Comparison VNF vs CNF

- Network Architecture Evolution: PNF -> VNF -> CNF
- CNF Testbed Project*
  - Compare VNFs on OpenStack with CNFs on Kubernetes
  - Workflow: Hardware provision -> Infra provision -> VNF, CNF deploy -> Testing
  - Network functions: Packet Filter, NIC Gateway
  - Use cases: service chaining, SR-IOV device plugin, multiple network paths
  - Preliminary results: CNF leads more metrics*
    - Deploy time, idle state RAM/CPU, throughput
    - Latency, runtime RAM/CPU

*https://github.com/cncf/cnf-testbed
Beyond Testing: Built-in Observability

- DevOps, development and operation together
- Observability: Metrics, Logging, Tracing
  - CNCF standard I/F: OpenMetrics, Fluentd, OpenTelemetry
- CNF design with built-in observability
  - Data source
    - Probes: kprobes, uprobes, dtrace probes
    - Tracepoints: compile tracepoints into CNF/program
  - Data extraction
    - Files(/sys/kernel/debug/tracing), system calls (perf_event_open)
    - eBPF program, attach to probes and tracepoints, send data back by BPF Maps
- Use cases: Interface changes, table/session updates

*https://github.com/iovisor/gobpf/blob/master/examples/bcc/strlen_count/strlen_count.go
Cloud-Native Networks Design Principles

• **Containerization**, network functions packed into containers
• **Stateless**, states stored separated in a CRD or DB, not local
• **Microservices**, complex network functions made by CNFs chaining
• **Dynamic orchestration** via Kubernetes
• **Configuration via ConfigMap** or other **declarative APIs**
• **Built-in observability**, compatible with CNCF standard interfaces
• **Software and hardware co-design**, hardware support via device plugin
Takeaways

• Extensibility is the foundation of Kubernetes’ success; CNI plugin and Device plugin promote various solutions and opportunities
• Cloud-native technologies and tools are fast growing; network domain could leverage their existing success to accelerate its own evolution
• Performance is always a challenge, eBPF brings a new way to improve Linux kernel; hardware acceleration could be more significant; co-design probably yields the best.
THANK YOU