SC24 *Network Research Exhibition: November 2024*

PolKA: Polynomial Key-Based Architecture for Source Routing

To support traffic engineering for data-intensive sciences

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PolKA: An Efficient Source Routing Approach to Meet the Requirements of Data Intensive Sciences

GNA-G

No tables in the core	Open source/ Interoperable	Support in prog. switches	Fixed length header	Topology agnostic multipath routing

PolKA: Polynomial Key-based Architecture for Source Routing Implementation

- A single user-defined encoded/decoded label defines the path: identifying each switch and port along the way
- Polynomial Residue Number System (RNS)
- Chinese Remainder Theorem (CRT)
- Packet forwarding based on mod operation: remainder of division, using switch CRC hardware for speed
- Transparently traverses fixed function switches in the path as needed

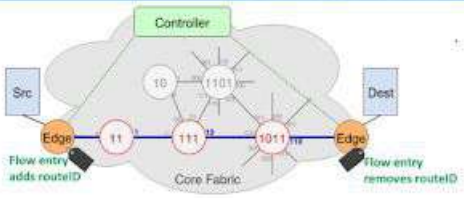
- **Easy Setup of paths/tunnels using a standard CLI**
- **Open Source Implementation in RARE/freeRtr**
- **Many powerful network applications:** Proof of transit, PBR, multipath, multicast, failure protection, telemetry, ...

SC24 NRE: PolKA Routing Approach to Support Traffic Engineering for Data Intensive Sciences

GNA-G

- **A robust,innovative approach to manage Terabit/sec competing data flows across complex intercontinental networks**
  - Balancing functionality, simplicity, performance and reliability
  - Able to adapt to changing flow profiles: policies, priority; progress versus deadlines; network segment, path and site states
- **Goal:** investigate whether the PolKA approach deployed using RARE/ freeRtr meets the needs of DIS networks, working with other software tools and subsystems developed by the GNA-G DIS-WG for constructing a packet-switched underlay network composed of network paths with bandwidth guarantees
  - That offers load balancing at the edge, prioritizing and scheduling flows over selected multi-domain paths.
- As a result, decisions can be taken in a coordinated way throughout the network, computing and storage resources to accelerate the science workflows.

How Does PolKA Work?



The **Controller** installs **flow entries** at the edges to add/remove ***routeIDs***.

- The **Controller** calculates the ***routeID*** using CRT:
  - Complexity: $\mathcal{O}(len(M)^2)$, where $M(t) = \prod_{i=1}^{N} s_i(t)$

R = 10000

routeID

nodeID polynomials

$s_1(t) = t^3 + t^2 + 1 = 1101$
$s_2(t) = t^2 + t + 1 = 111$
$s_3(t) = t^3 + t + 1 = 1011$

portID polynomials

$o_1(t) = 1$
$o_2(t) = t = 10$
$o_3(t) = t^2 + t = 110$

- Forwarding:

portID = < routeID >$_{nodeID}$		
1	=	<10000>$_{1011}$
10	=	<10000>$_{1111}$
110	=	<10000>$_{1011}$

Calculate routeID with CRT

$t^3 \equiv 1 \mod (t+1)$
$t^3 \equiv t \mod (t^2+t+1)$
$t^3 \equiv (t^2+t) \mod (t^3+t+1)$
$t^3 = 10000$

PolKA Innovations Demonstrated

- **Data plane**
  - Source Routing with Stateless Core
  - Forwarding at line rate by reusing CRC hardware in P4 programmable switches
- **Control plane**
  - Easy to configure tunnels
  - Integrated in the FreeRtr platform
- **Supporting:**
  - Big pipes/tunnels configured in a underlay network
  - Massive data transfer with aggregation of many large flows
  - Dynamic traffic steering configured at the edge
  - Flow Steering exploiting PolKA properties (e.g. stateless core nodes)
    - Explicit path and TE at the edge and in the core

SC24 PolKA Capabilities and Demonstrations

Capabilities:

- The PolKA protocol enables Path Aware Networking with a dynamic, highly adaptable approach to traffic steering across networks
- Using path identifiers that explicitly encode routes at the network edge, PolKA allows core nodes to remain stateless, significantly simplifying routing decisions
- This design ensures that packets follow specific, predefined paths without the need for the core network to store complex state information.
- With PolKA, traffic flows can be steered dynamically based on network conditions, enabling more efficient use of network resources, improved resilience, and an optimized load distribution

Demonstrations:

- Transferring a data tsunami from UFES (Brazil) to the Caltech booth across multiple 100G & 400G continental and transoceanic networks;
- Using PolKA and M-PolKA to showcase:
  - Path Aware Networking for data intensive traffic flows with highly adaptable, dynamic traffic steering, and agile path reconfiguration
  - Traffic engineering with optimized flow allocations based on the Quantitative Theory of Bottleneck Structures and GradientGraph, on top of PolKA underlay tunnels
  - Conducting experiments to steer traffic using PolKA within the FABRIC int'l testbed