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PolKA: Polynomial Key-based Architecture for Source Routing

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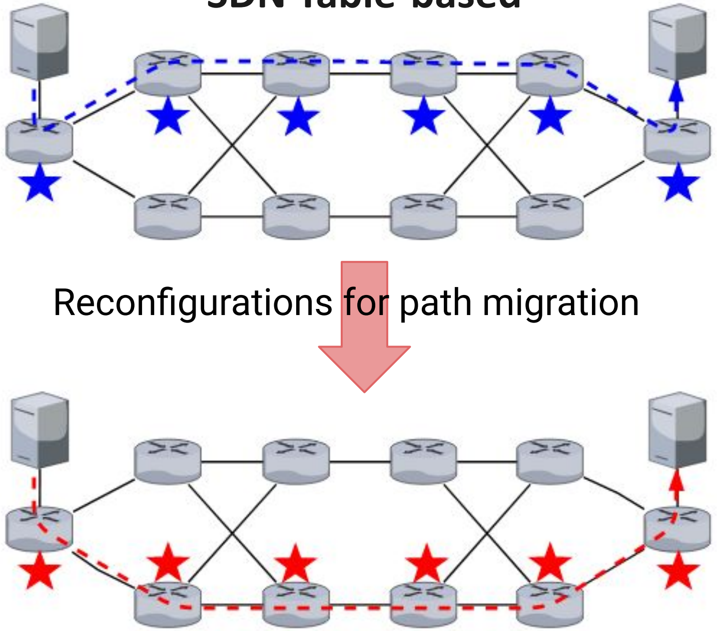
Which PANRG's problem does PolKA solve?

- “(...) Endpoints have very little information about the paths over which their traffic is carried, <u>**and no control at all beyond the destination address**</u>. (...)”

PANRG: The Control Problem

- “(...) Endpoints have very little information about the paths over which their traffic is carried, **<u>and no control at all beyond the destination address</u>**. (...)”

SDN Table-based



Can SDN table-based solutions offer path-aware control?

- **Problems:**
  - Large number of states ⟶ **Scalability** 🙁
  - Limited capacity of tables ⟶ **Granularity** 🙁
  - Latency for path configuration ⟶ **Agility** 🙁

PANRG: The Control Problem

- "(...) Endpoints have very little information about the paths over which their traffic is carried, **and no control at all beyond the destination address**. (...)"

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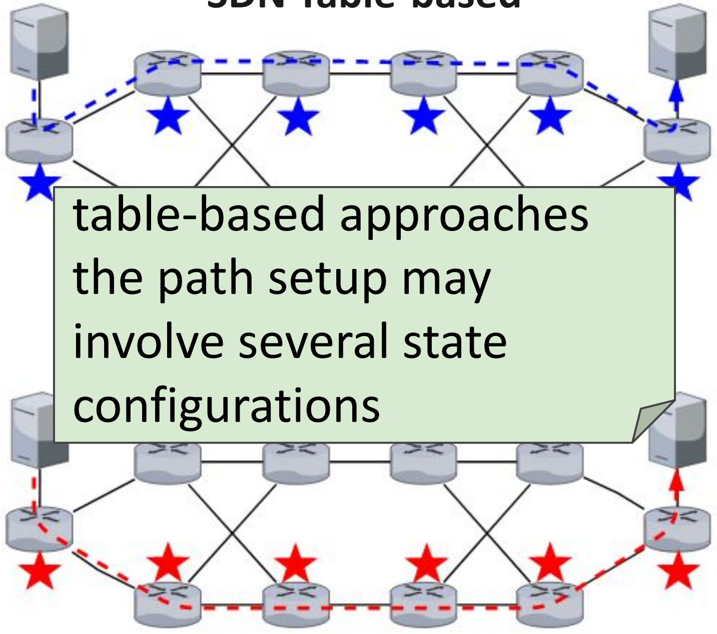

table-based approaches the path setup may involve several state configurations

Can SDN table-based solutions offer path-aware control?

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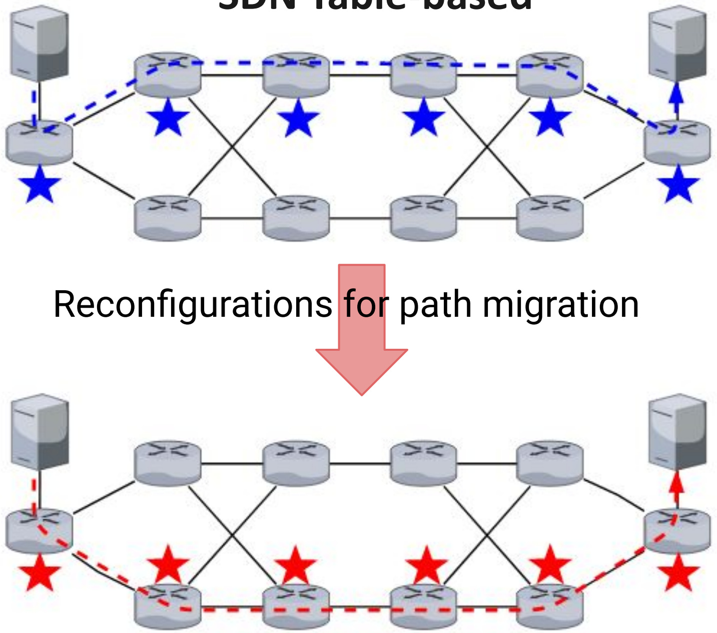
  - Latency for path configuration ⟶ **Agility** 🙁

Source Routing: a key mechanism for endpoints

- **Endpoints controlling paths**: setup *routeID* at the edges

SDN Table-based



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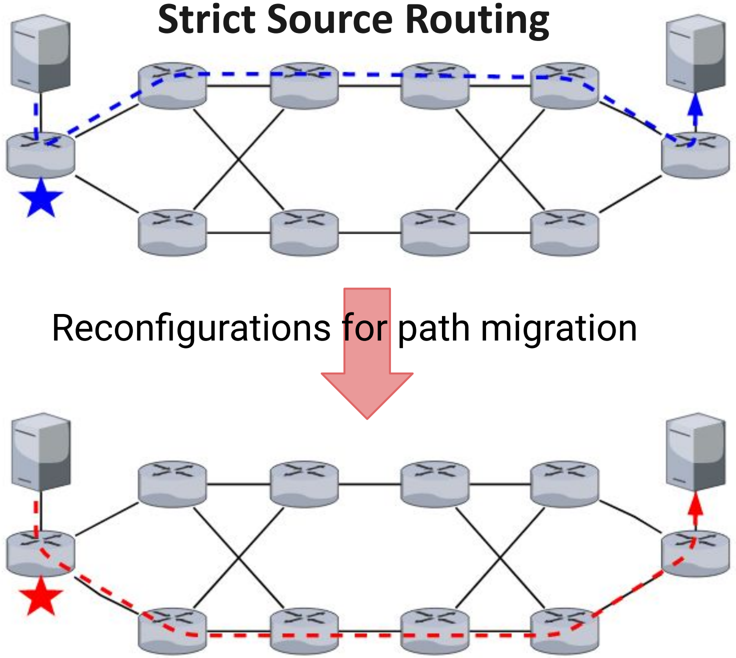
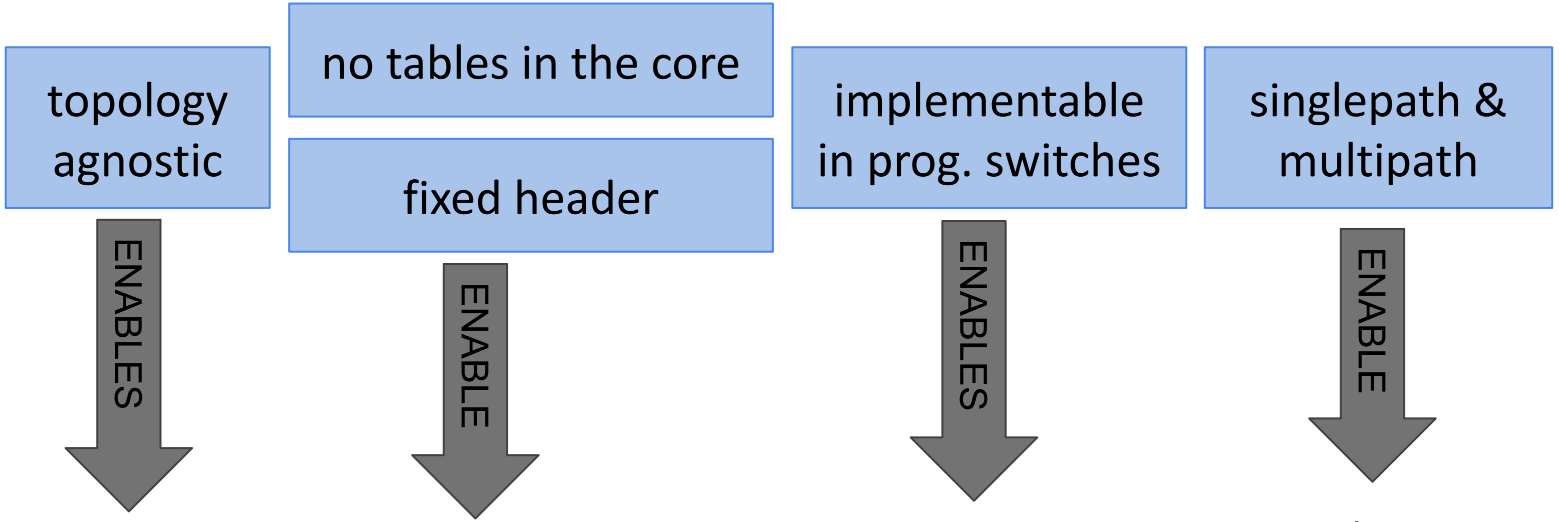
Strict Source Routing



Why use PolKA as Strict Source Routing?

- Only PolKA Source Routing simultaneously meets the following requirements:



- general solution for path-aware networking

- fast path reconfiguration
- no var header limitation with respect to hop limit

- exploit wire-speed and low latency dataplanes

- path expressiveness
- reliability by exploring multiple paths
- efficient in-band telemetry

How does PolKA work?

- Three polynomials:
    - **routeID**: a route identifier calculated using the CRT (Chinese Remainder theorem).
    - **nodeID**: to identify each core node.

      - Irreducible polynomial
    - **portID**: to identify the ports of each core node.

- The forwarding uses a **mod** operation (remainder of division):

$$\boxed{\textbf{portID} = \langle\, \textbf{routeID} \,\rangle_{\textbf{nodeID}}}$$

Timeline

PolKA received the 2021 Google Research Scholar Award

M-PolKA received the Intel Connectivity Research Grant (Fast Forward Initiative)

2020	2021/1	2021/2	2022
PolKA paper IEEE NetSoft	**IEEE ONDM paper Deployment @ Pan-European GÉANT Testbed RARE**	**Integration with RARE+FreeRouter**	**M-PolKA paper IEEE TNSM** *(accepted for publication)*
Novel **Polynomial RNS-based SR and reuse of CRC hardware**	PolKA **data plane implementation** in intercontinental testbed	PolKA **data & control plane implementation** + **integration**	Extension to **multipath SR** for reliable communications
Emulated prototype in Mininet & Hardware prototype in SmartNICs	Hardware: Intel Tofino	Emulated prototype in FreeRouter & Hardware prototype in Intel Tofino with FreeRouter control plane	Innovative apps: inband network telemetry, and load balance

How to implement PolKA?

- **Reuse CRC hardware** to offer polynomial mod.
  - Externs in P4 language.
  - Support in high-performance Tofino switches.
- RARE: Open source full-featured router on networking hardware for R&E
  - **data plane:** P4 (bmv2 and Tofino) and DPDK
  - **control plane:** FreeRouter
    - Reuse of standard distributed protocols
    - Static table maps Segment Routing indexes to nodeIDs
    - Get available topology info from link-state protocols

AMS
POZ
FRA
BUD
GÉANT
RARE

How does PolKA work?

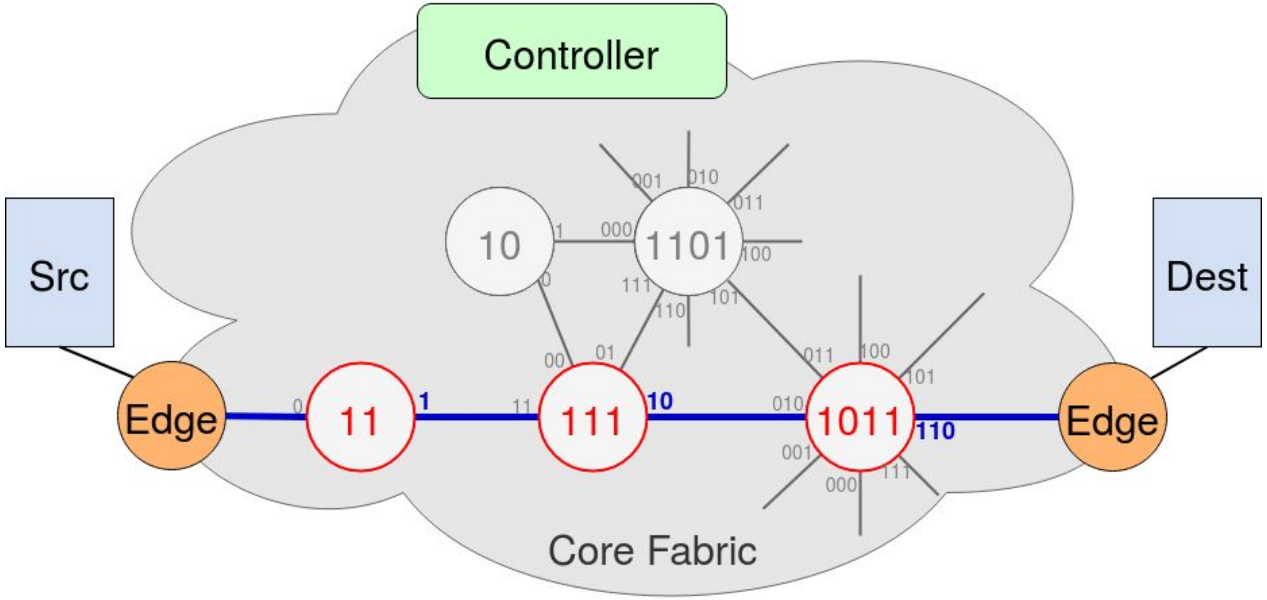
- The **Controller** chooses a **path** for a specific flow:
  - A set of switches: {0011,0111,1011}
  - and their output ports: {1 , 10, 110}

nodeID polynomials

$$s_1(t) = t + 1 = 11$$
$$s_2(t) = t^2 + t + 1 = 111$$
$$s_3(t) = t^3 + t + 1 = 1011$$

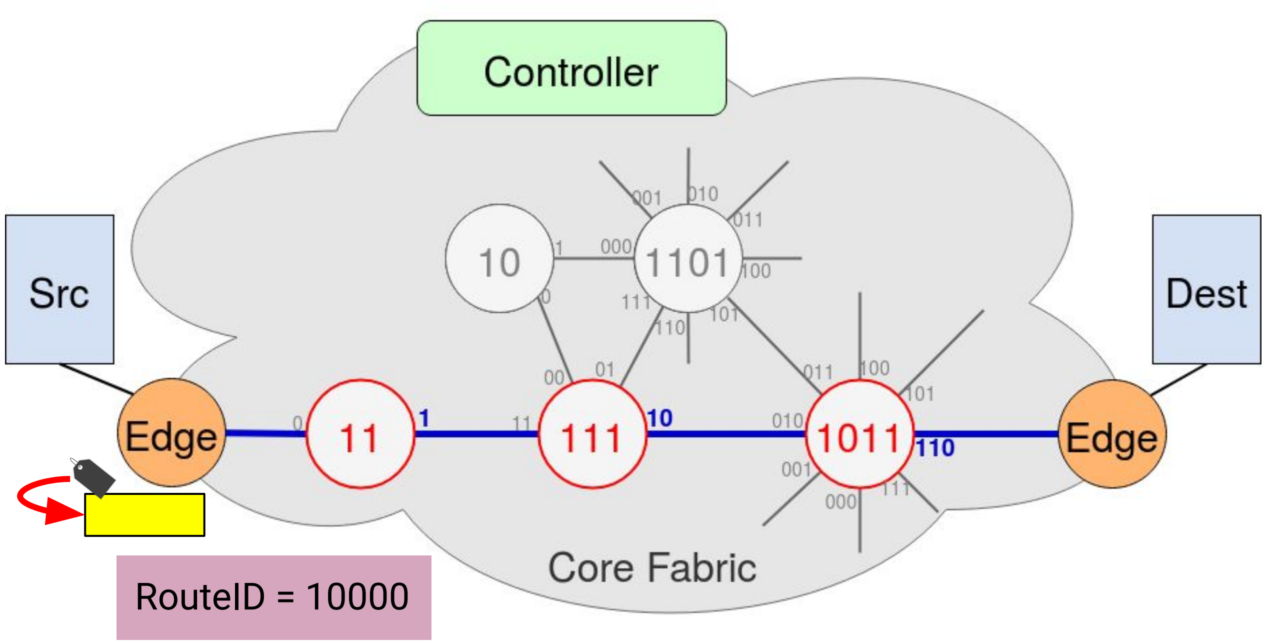
portID polynomials

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



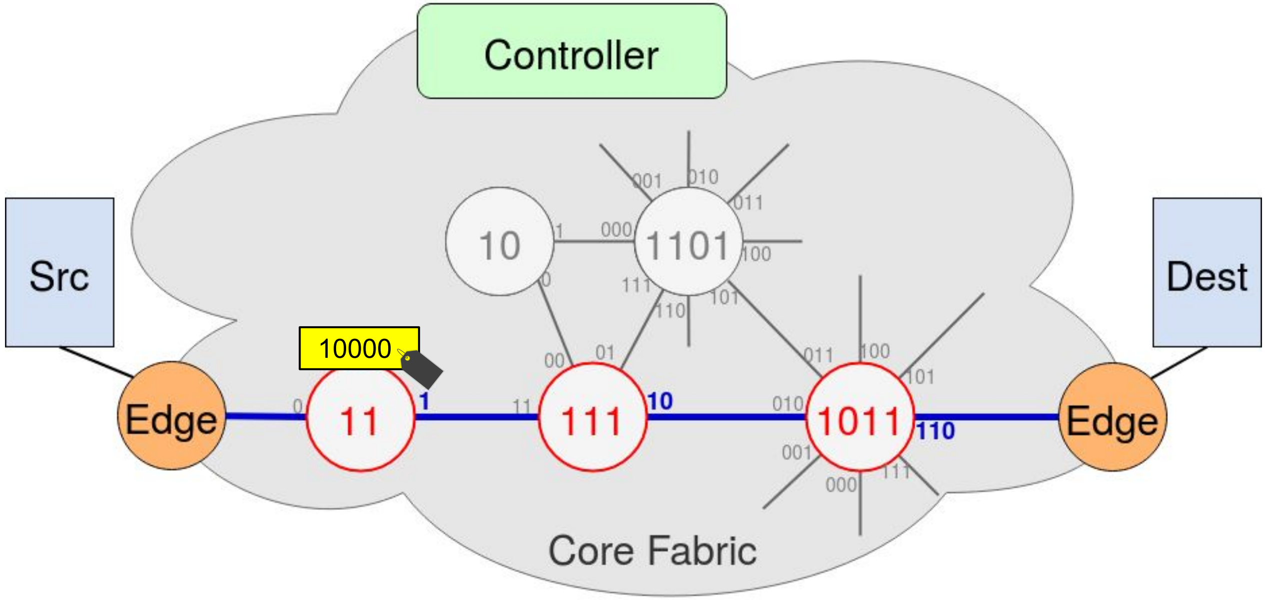
How does PolKA work?

- When packets arrive, an action at ingress embeds *routeID* into the packets.



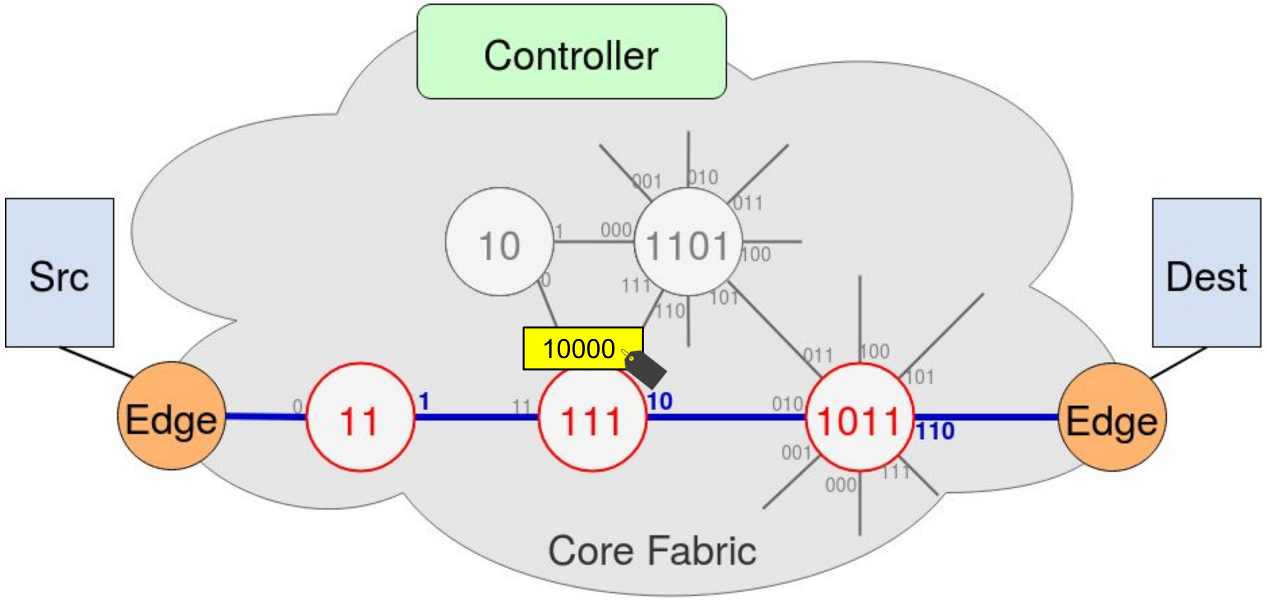
How does PolKA work?

- Forwarding using **mod** operation: $\langle 10000 \rangle_{0011}$ $= 1 \rightarrow$ output port
- No *routeID* rewrite! No tables!



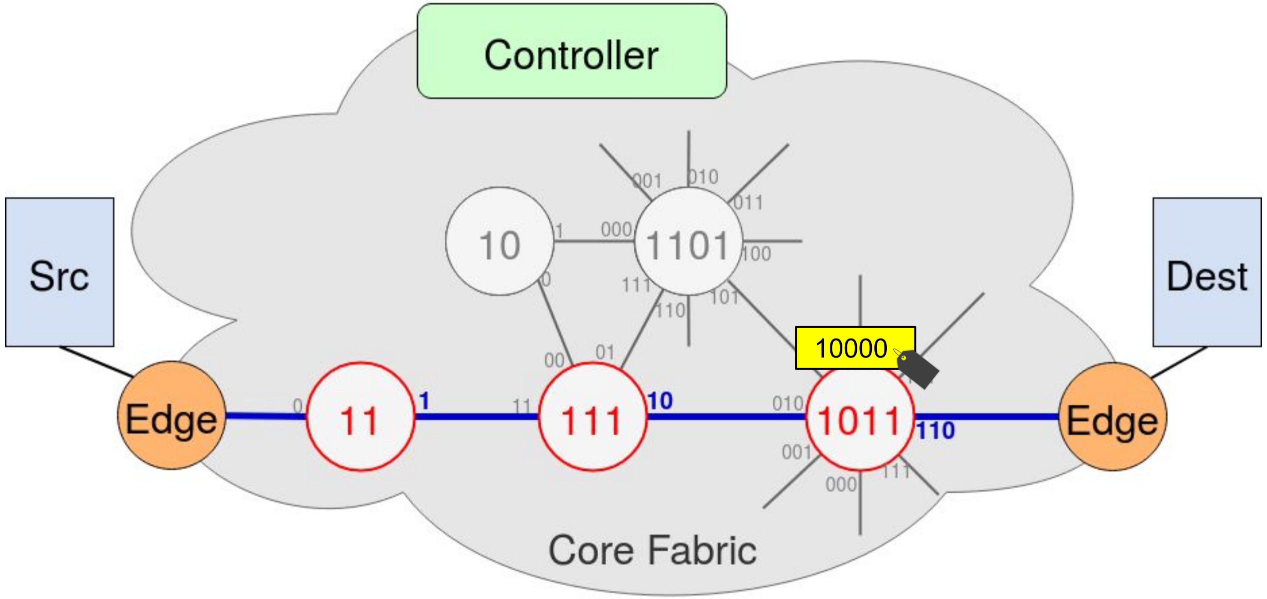
How does PolKA work?

- Forwarding using **mod** operation: $<10000>_{0111}$ = 10 ⟶ output port
- No *routeID* rewrite! No tables!



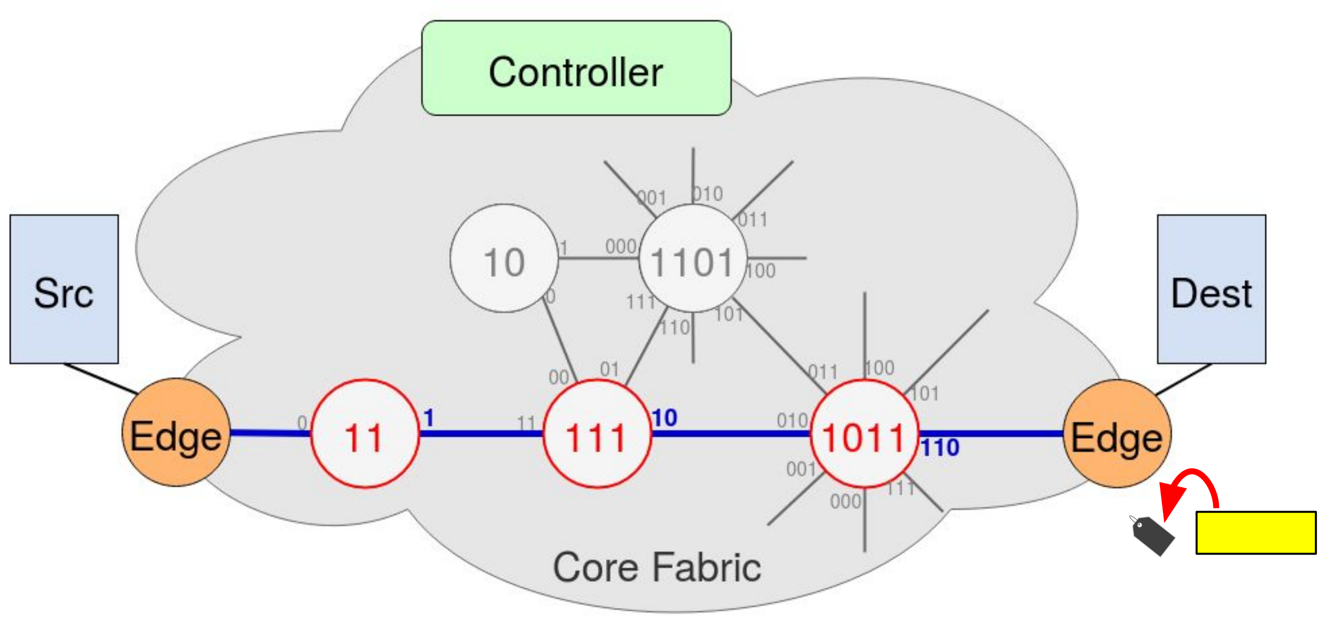
How does PolKA work?

- Forwarding using **mod** operation: $\langle 10000 \rangle_{1011}$ = 110 → output port
- No *routeID* rewrite! No tables!



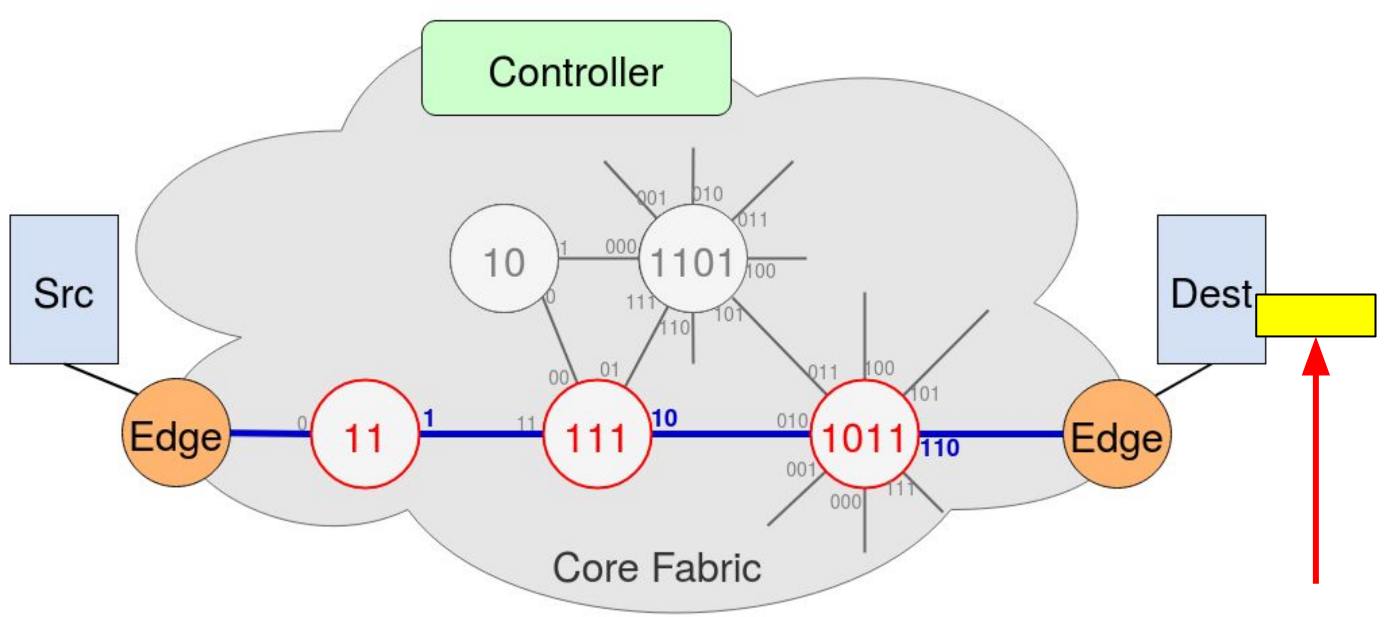
How does PolKA work?

- Finally, an action at edge egress node removes *routeID*.



How does PolKA work?

- Packet is delivered to the application in a transparent manner.



Thank you!

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