Load balancing challenges in AI fabric

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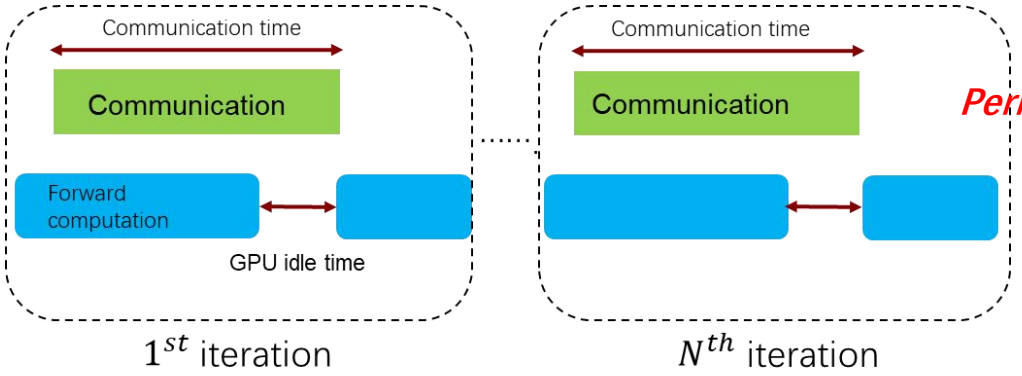
AI Traffic pattern challenge

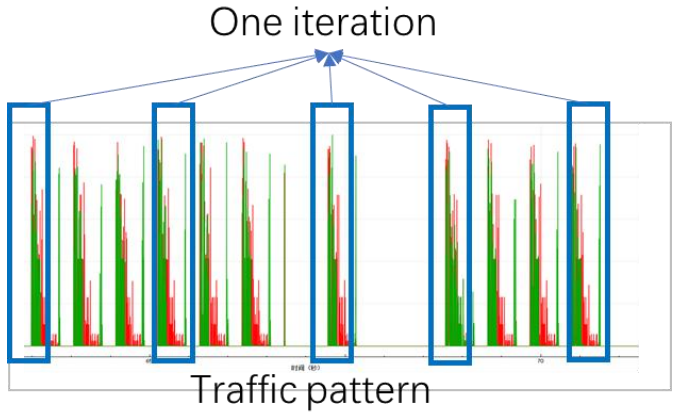
Traditional DC Traffic pattern

- Many asynchronous small BW flows.
- Chaotic pattern averages out to consistent load.

AI Traffic Pattern



Periodical



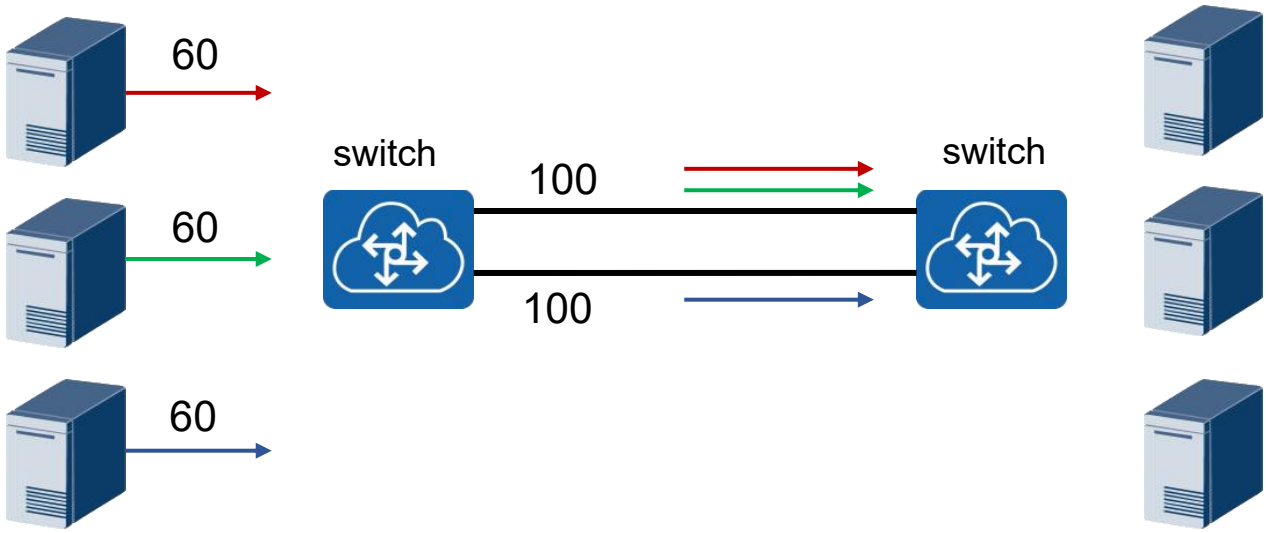
Burst

- Few synchronous high BW flows.
- Synchronization magnifies long tail latency and bad load balancing decisions.

Traditional flow-based LB perform poorly

- **Flow-based load balancing means switches distribute packets to multiple paths in the flow granularity, and Packets within a flow take the same forwarding path.**

- **The inherent drawback of flow-based LB is its coarse granularity:**
  - It does not take into account the size of different flows;
  - Especially in AI fabric, it's hard to balance the few and high bandwidth flows well.

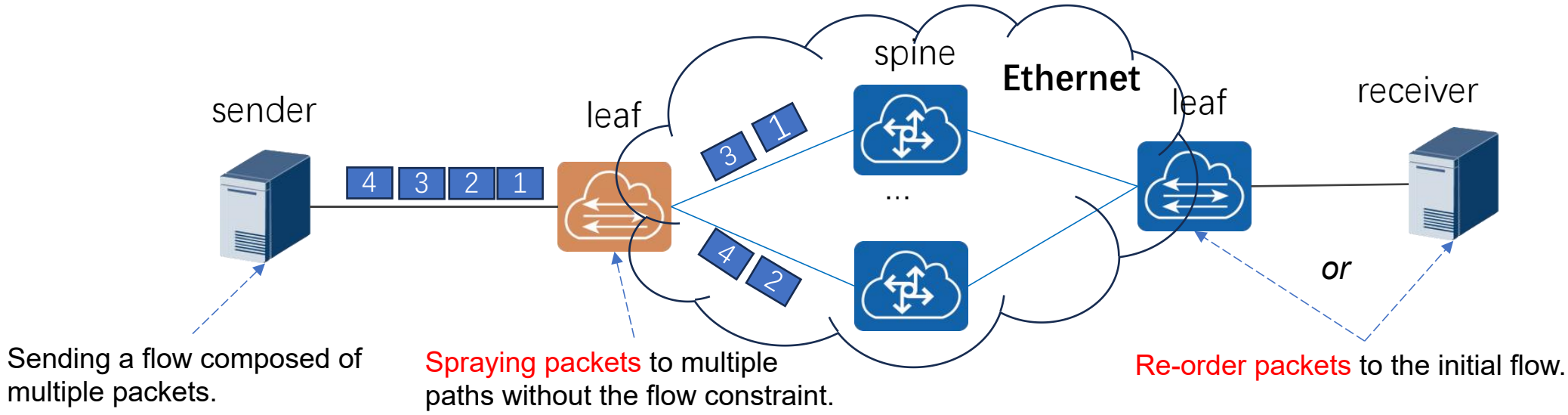


Example

- When the number of flows is not divisible by the number of available paths, it' s impossible to get an optimal balance using flow-based LB.

Packet-spray-based LB become the trend for AI fabric（1）

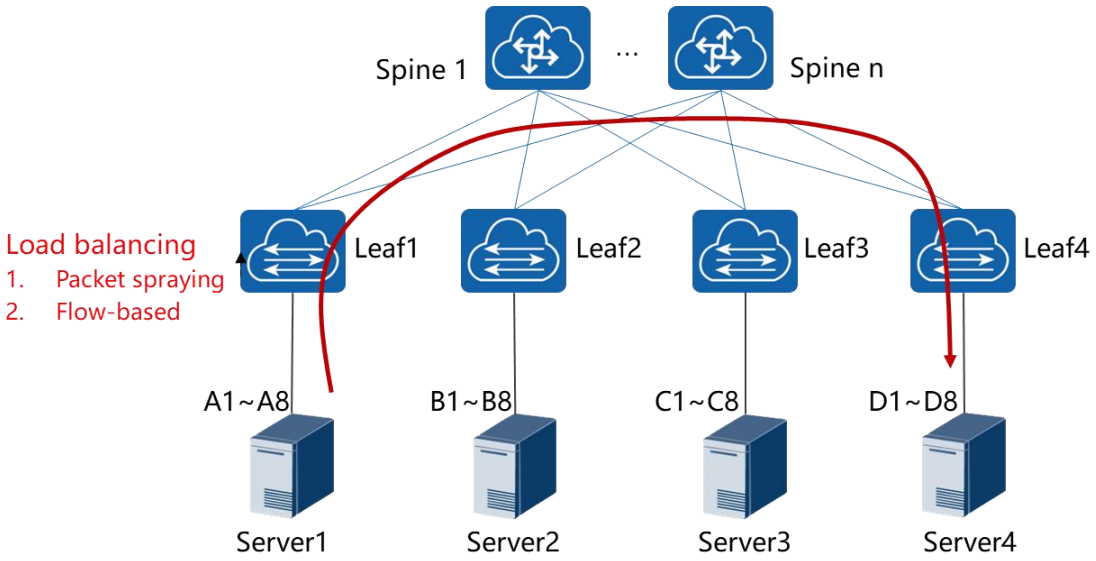
- **Packet spray means switches distribute each packet to multiple paths independently, making the load on the network more balanced than flow-based.**
- **There are several routes supporting packet spray:**
  - Cell-based in dedicated network or ethernet-based：Standardization → ✔ **Ethernet-based.**
  - NIC-driven or Network-driven: Applicable to different scenarios. → Focus on **network-driven** solution in this document.
- **Basic Architecture of network-driven packet spraying in ethernet:**



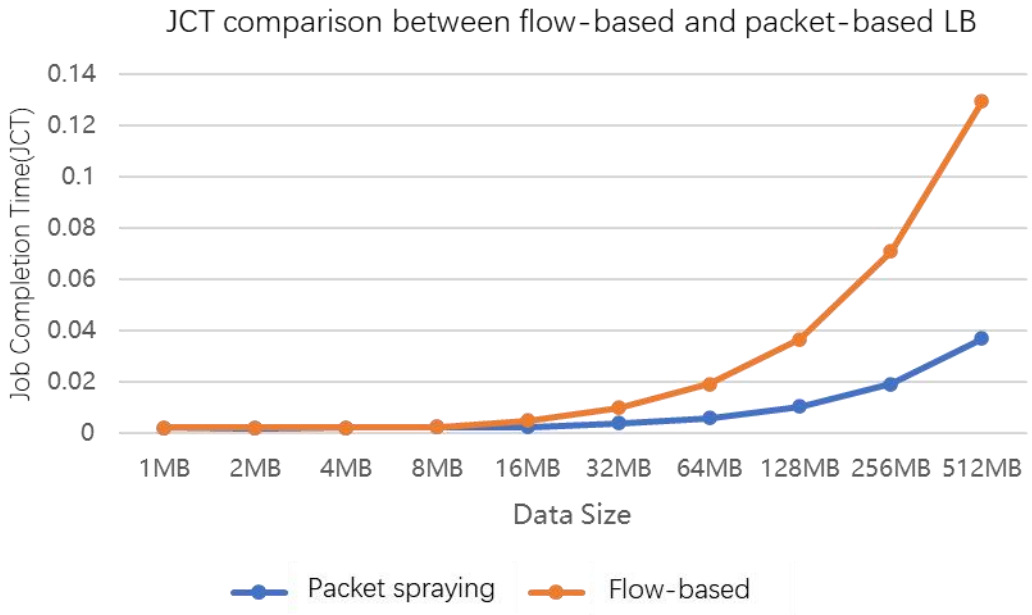
Packet-spray-based LB become the trend for AI fabric (2)

- **We conduct an experiment to evaluate the performance of flow-based and packet-spray-based LB.**

Experiment settings



Results



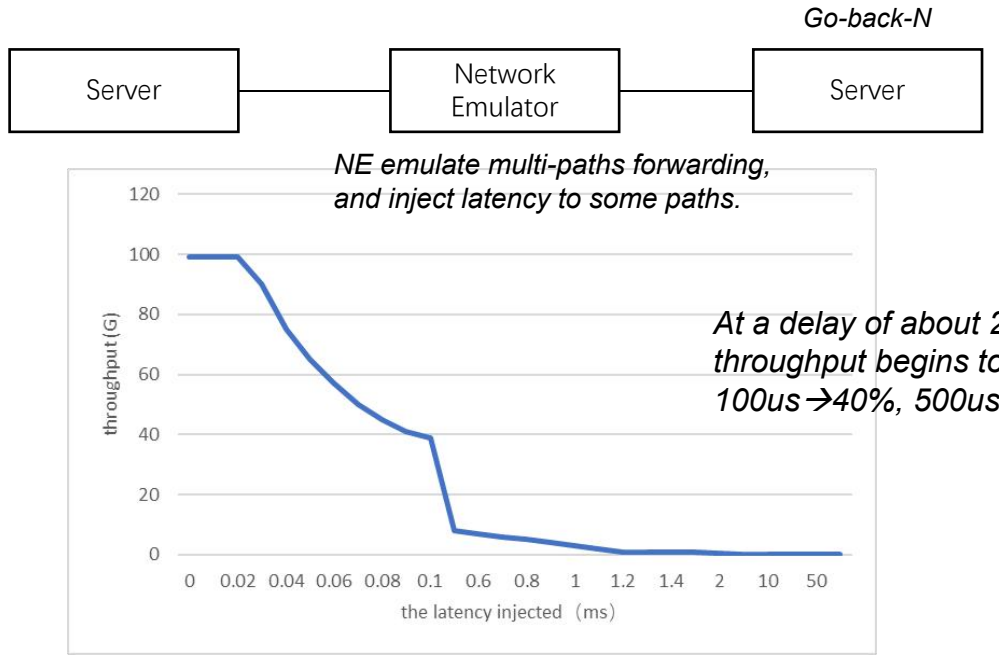
- The topology is the classic two-layer clos network, 4 servers, 8GPU with 8 NICs in a server.
- There are 8 jobs running: A1~D1、A2~D2….A8~D8.

- Testing the task completion time (JCT) of flow-based and packet-spray-based load balance under different message size.
- In a 512MB scenario, JCT of packet-spray-based LB is reduced to about one-third compared to flow-based.

Challenges in Packet-spray-based LB

- **The main side-effect of packet-spray-based LB is causing packets of a flow arriving at receiver out of order:**
  - Re-order problem.
  - **Reliability problem: Loss-detection and retransmission;**

- **Out-of-order cause performance degradation significantly under Go-back-N mechanism.**
  - The mainstream RNIC adopt Go-back-N mechanism to provide reliability.
  - A lot of out-of-order packets may trigger frequently Go-back-N, resulting in a precipitous decline in throughput, as shown in the right emulation.



- **RNIC can adopt Selective ACK to improve GO-back-N, but still existing problems hindering performance.**
  - The receiver can not directly determine whether the packet is lost or just out of order through the PSN,
  - relying on the timeout mechanism to detect packet loss reduces the sending rate.
  - Accurate fast-retransmit is necessary, but only by receiver is often not possible.

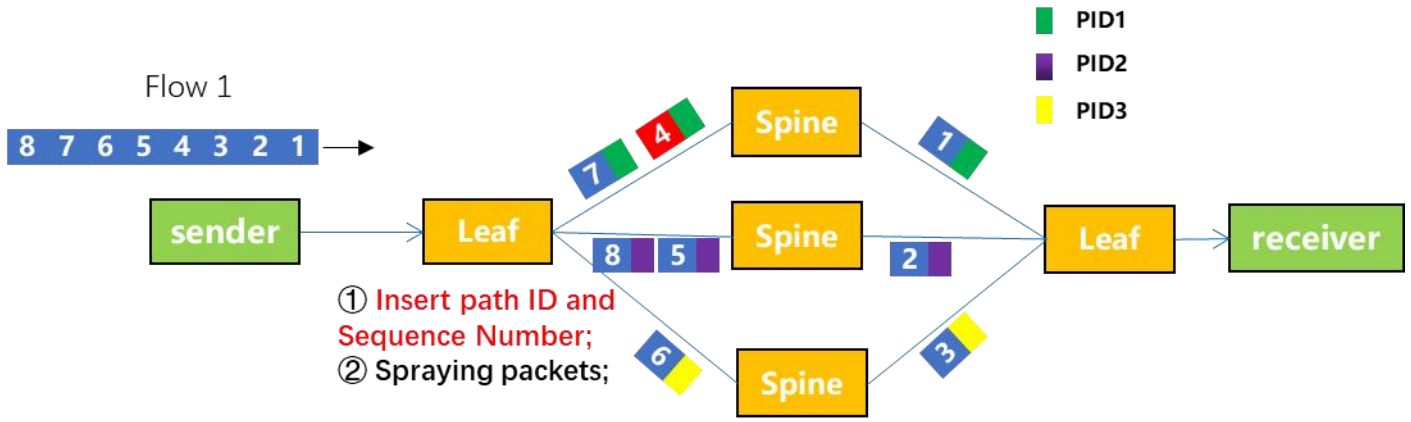
- **A preliminary conclusion is that processing out-of-order packets exclusively on the receiver NIC can hardly achieve optimal performance.**

Network can do more…

- **In packet-spray-based LB, the root difficulty of receiver dealing with out of order packets is that it does not know the forwarding path and state of each packet.**
- **An intuitive solution is that network provide receiver the path information of packet forwarding to help loss detection and fast retransmission.**

Key idea: network device insert the path information(e.g. Path ID) into packet header, so that the receiver can detect the loss more quickly and execute fast retransmission.

Example



③ Packets of one path arrive the Receiver in order. NIC can quickly detect the loss packet based on the path id and sequence number in a path;

Summary

- **Introduce the drawbacks of traditional flow-based ECMP for AI fabric, and packet-spray-based load balancing become the trend.**
- **Analyze the challenges bring to receiver in packet-spray-based load balancing.**
- **Network can assist receiver to solve the challenges.**
- **Potential Standard Requirements:** Need to standardize path information in L2 for network-assisted fast retransmission, such as path ID.

Next Action

- **Propose a Study/Work Item：** Packet-Spray-Based AI Fabric
- **Scope：** Packet-Spray-Based Load Balance 、Packet-Spray-Based Congestion Control、Reorder、Ethernet QoS、Telemetry、high-precision OAM、Protection etc.

Thank You !