In-Network Data Consistency (INDAC)

IETF 119 CCO Side Meeting

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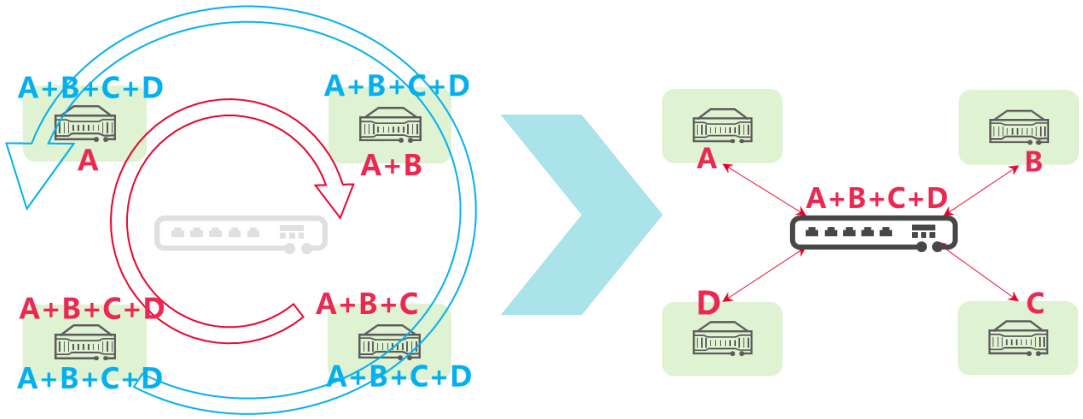
In-Network Computing: Embed computing process in network

- Recently, In-Network Computing (INC) has been used in the AI training, BigData and HPC to accelerate the data aggregation process.
- INC leverages convergence position and high throughput capability of switches to aggregate data on-path, eliminating 50% data movement[*].



INC: In-network aggregation
Data aggregation during communication

Forward

Forward + Compute

INC reduces node interaction times and data transmission amount by 50% [*].

[*] Lao C L, Le Y, Mahajan K, et al. {ATP}: In-network aggregation for multi-tenant learning[C]//18th USENIX Symposium on Networked Systems Design and Implementation (NSDI 21). 2021: 741-761.

In-Network Computing has more potentials than just aggregation

What are the strengths of INC switch?

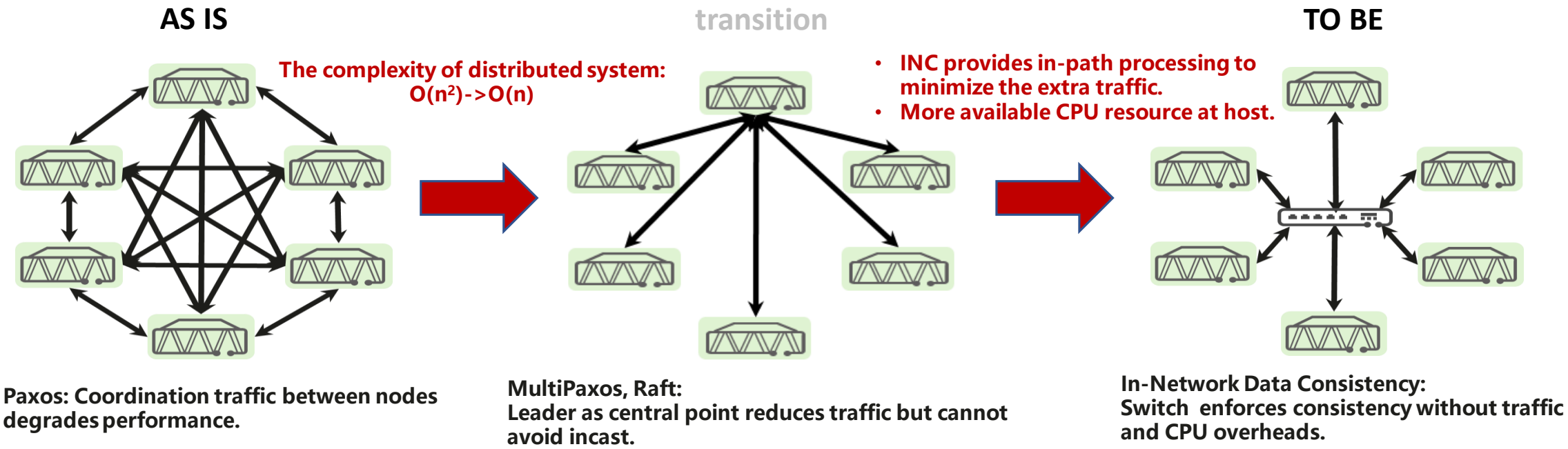
- At the convergence position of the network, switch can see all the traffic passing through, which can build a global view.
- Switch memory available for packet/flow level state information maintenance.
- Switch can provide various arithmetic operations in addition to sum(aggregation) when doing line rate forwarding.

INC can do more in

- Distributed storage
- Database
- Cloud

In-Network Data Consistency(INDAC)

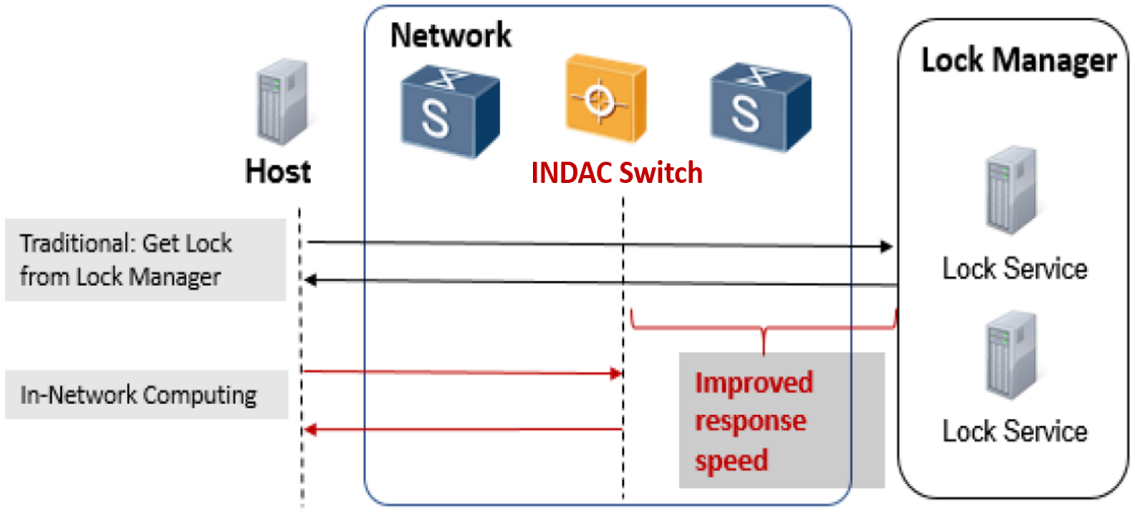
- In distributed systems, **data consistency** management involves complex coordination and synchronization mechanisms between nodes, such as locking and consensus protocols.
- Most mechanisms introduce **extra traffic and CPU consumption overhead** either between peer nodes or between a single server and other nodes. The overall system performance including latency, throughput and scalability is not optimal.
- INC provides new opportunities to achieve data consistency with lower latency and higher throughput.



Maintain the global consistency info in switch to accelerate consistency protocols.

An INDAC example for Concurrency Control: Lock mechanism enhancement

Switch grants lock to hosts with short latency and ~10TB throughput.



Server CPU ➔ Switch Pipeline

Concurrency Control: For database and file system, lock is a common mechanism to achieve concurrent read/write data consistency.

Why INDAC accelerates consistency?

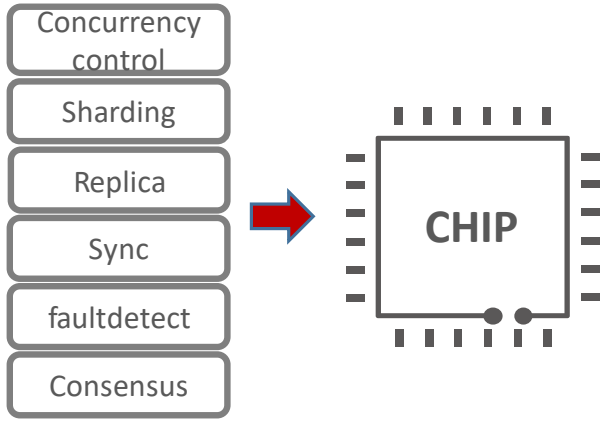
- Switch memory records consistency information. When packet passes through switch, check the record and modify the packet.
- Switch processes faster and more stable than CPU, ~ns for one packet.
- Switch has much higher throughput, i.e., >10TB, which can achieve billion PPS.

A general-purpose INDAC framework and the challenges

Starting from the lock function, we can build a general purpose In-network data consistency enforcement framework to support multiple consistency-related function accelerations, e.g., concurrency control, replica, data sharding, synchronization, and etc.

Challenge 1： Put many INDAC functions into one chip?

- The available memory resource is limited, usually less than MB.
- The logic resource is also limited and should not affect the line-rate forwarding.

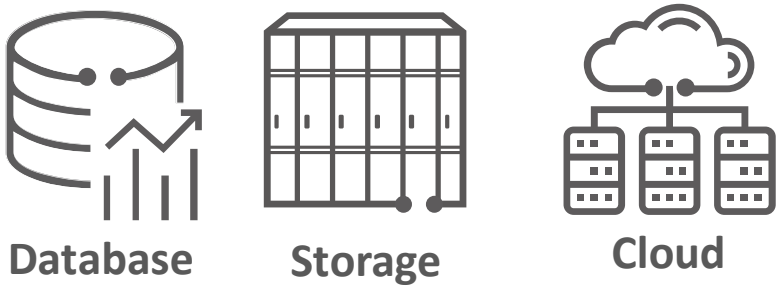


Challenge 2： Coordinate server and switch to realize every INDAC function?

- Different INDAC functions have different data handling process, different match action table, different packets and etc.

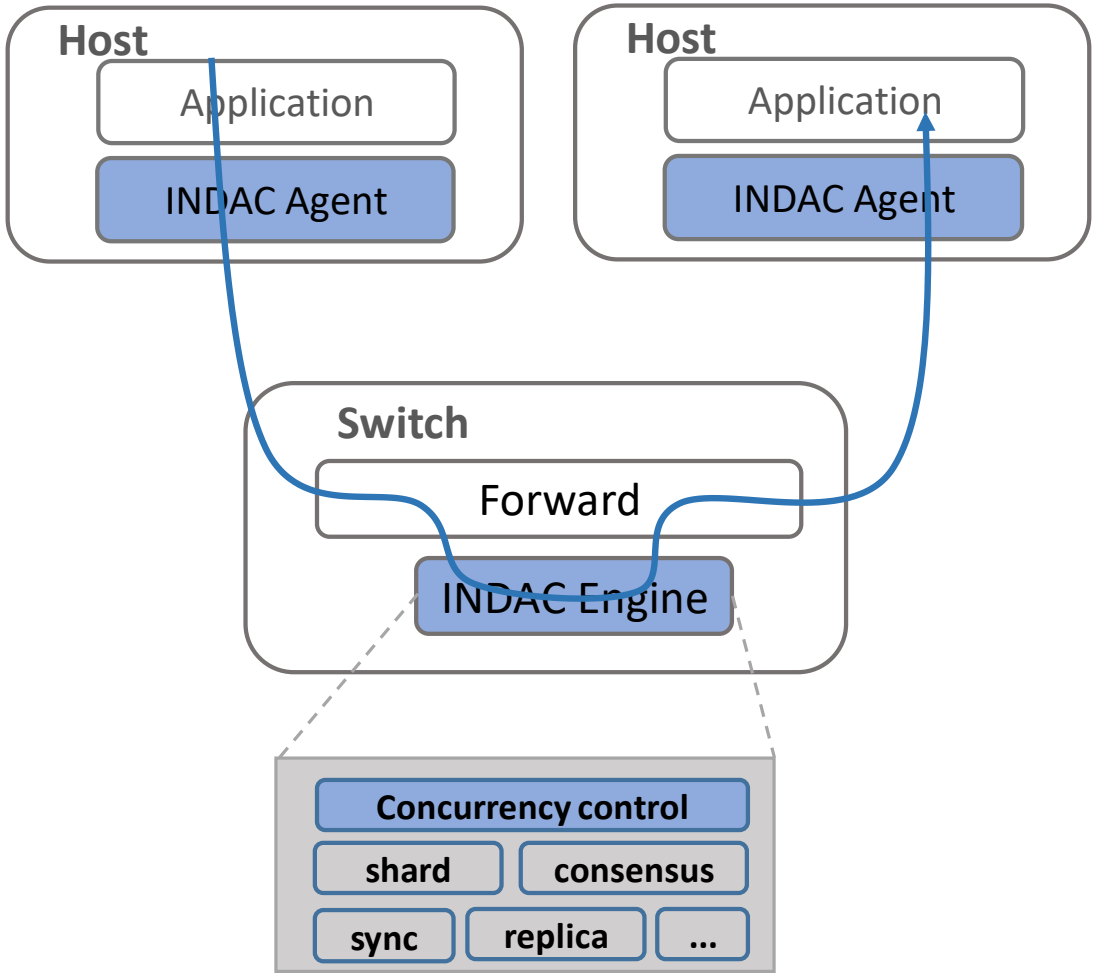
Challenge 3： How to support different applications?

- Different application has different software API, lib, data structure and etc.



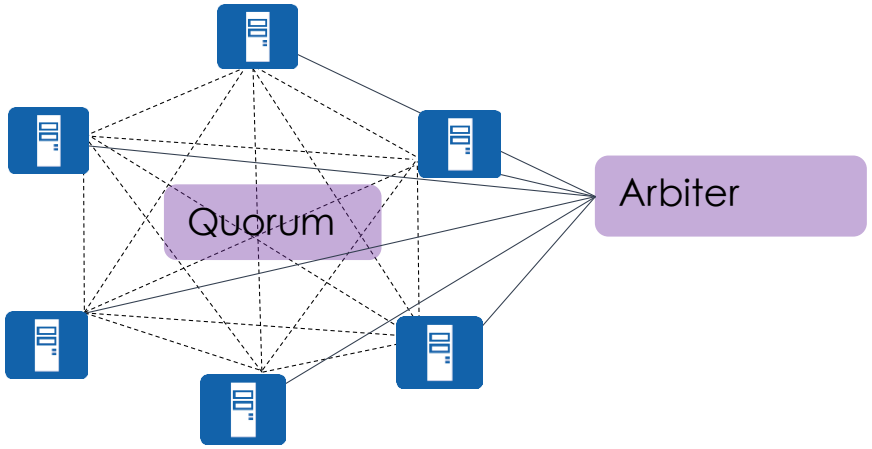
INDAC framework to support multiple DAC functions

- ✓ **Co-design system:**
  - **INDAC engine in switch** provides INDAC functions
  - **INDAC agent in host** provides common API to support different applications
- ✓ **Protocol between INDAC agent and engine:**
  - Identify INDAC packet
  - Identify the specific INDAC function
- ✓ **Hardware Resource:** Function abstraction and memory compression facilitate the use of small memory to support multiple INDAC functions.
- ✓ **Flexibility:** Programmability of the INDAC engine provides opportunities to implement new functions in the future.
- ✓ **Fallback plan:** In case of switch down and memory used up, INDAC supports fallback to original consistency enforcement mechanism.



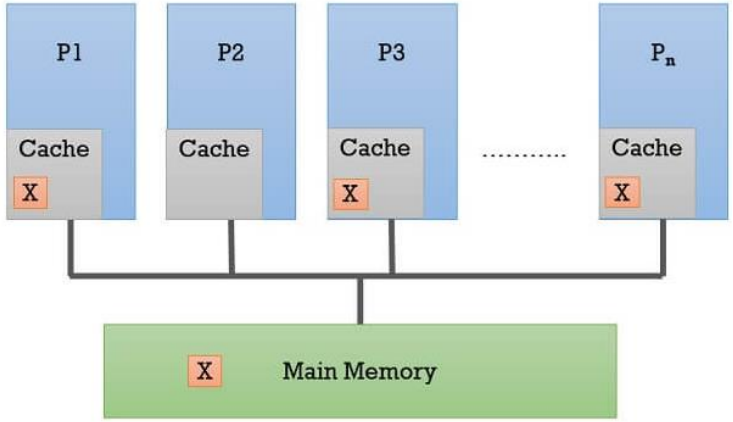
Future work: more INDAC function

Network Arbitration



- In case of node failure including split-brain, distributed system needs a new leader for arbitration.
- Switch is a good candidate for INDAC arbitration function.

Cache Coherence



- Multiple CPUs can read/write shared data in cache, which needs to ensure consistency. Supported in CXL and etc.
- Possibly implemented as INDAC function in other devices like DPU.

Thank you