FOSDEM

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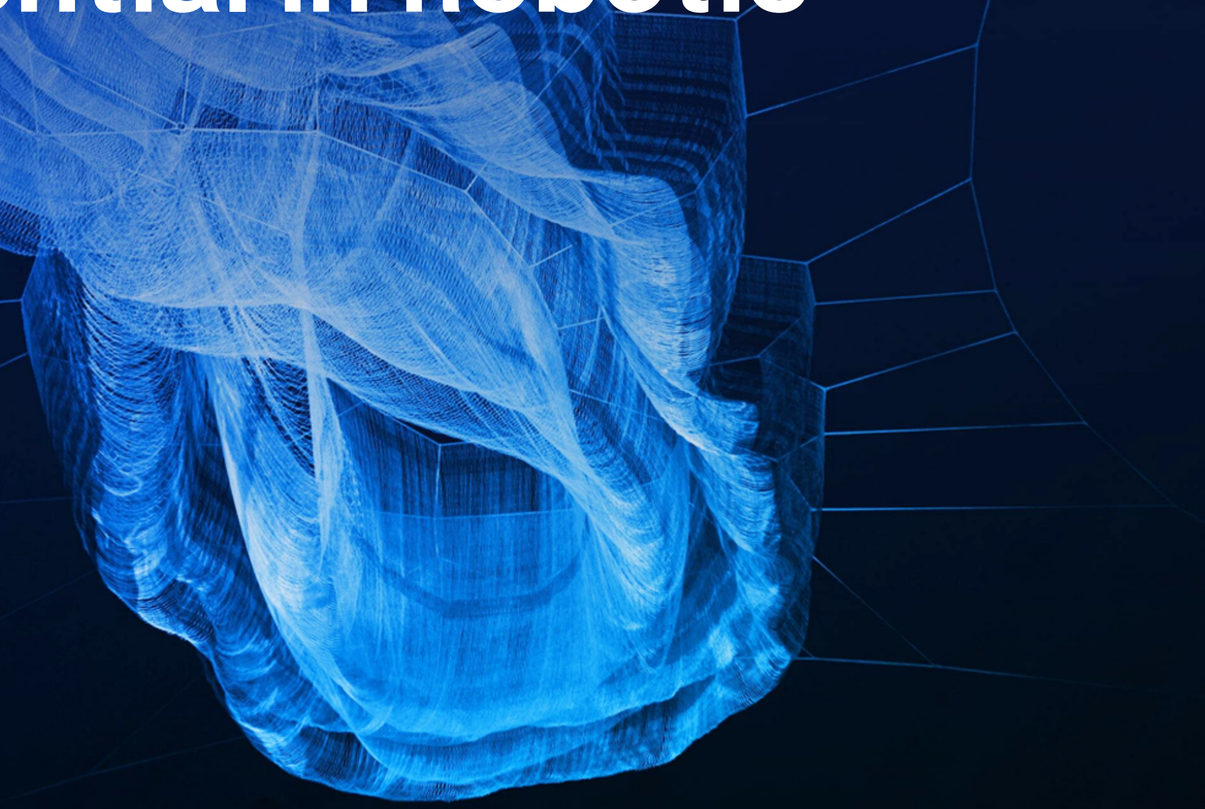
Eclipse Zenoh: Understanding the Protocol and its Potential in Robotic



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Robotic Software: Which Architecture ?

Layered Architecture ?

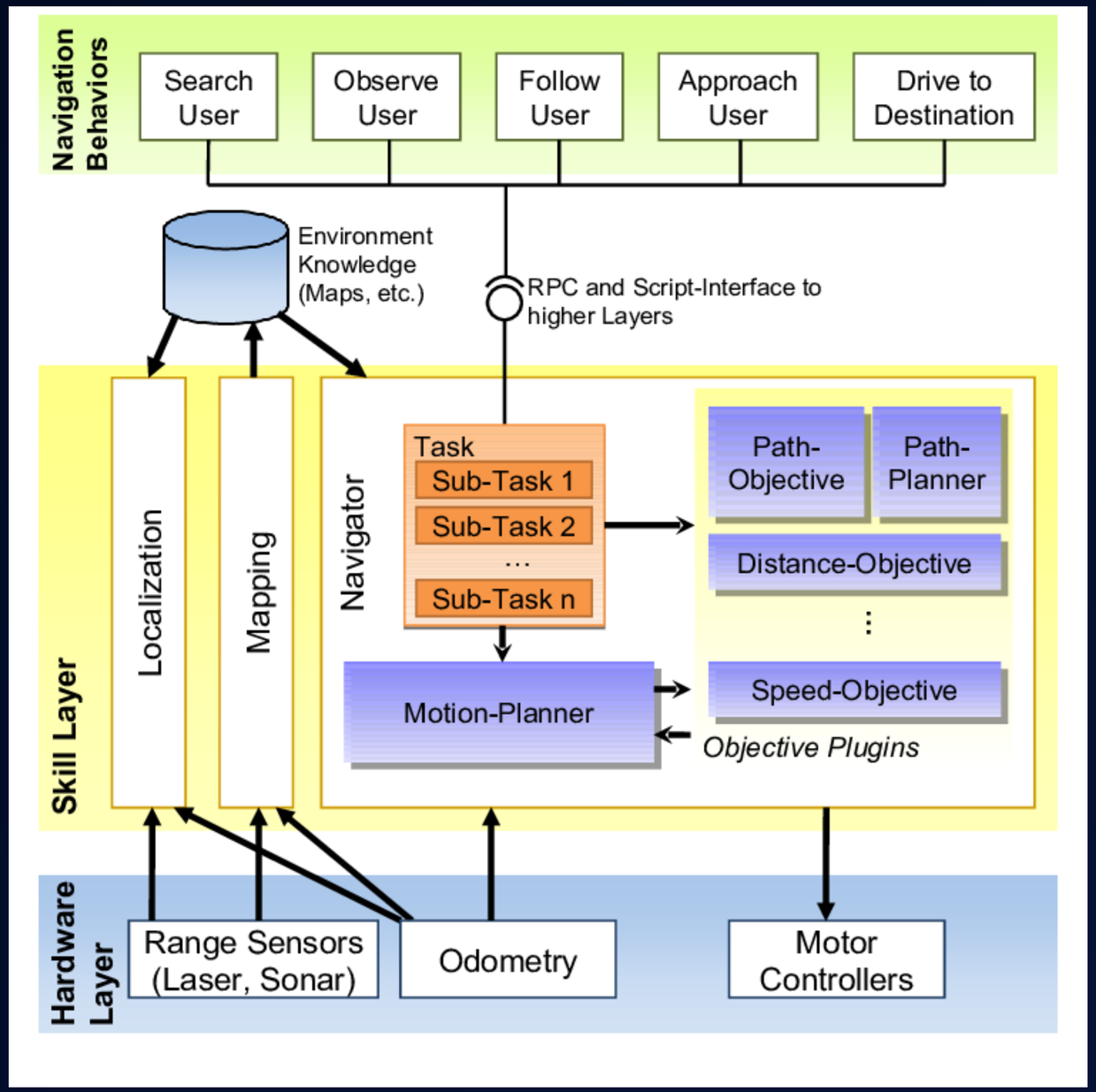


image: Gross et al. 2011
https://doi.org/10.1109/ICSMC.2011.6084050

Data Pipelines ?

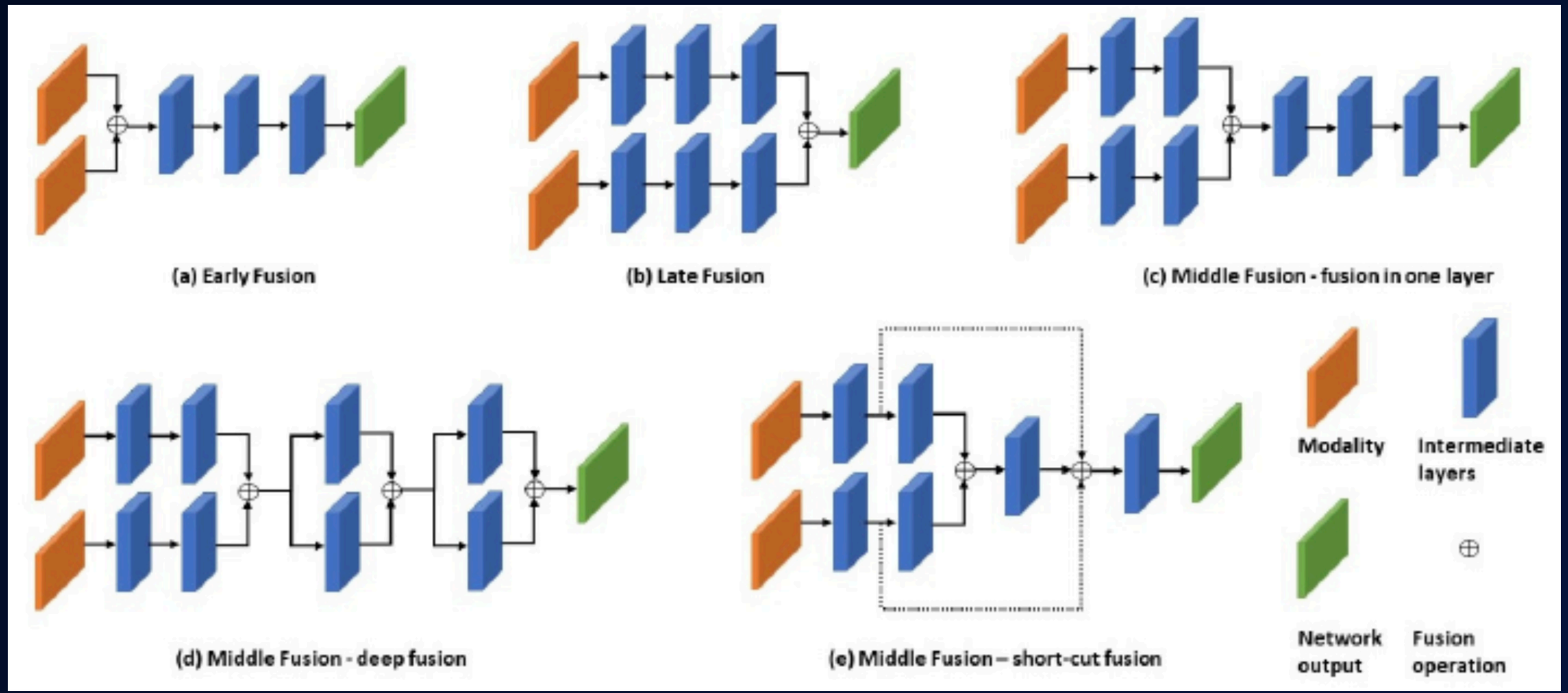


image: Borges et al. 2022
http://dx.doi.org/10.55417/fr.2022049

Data Flows ?

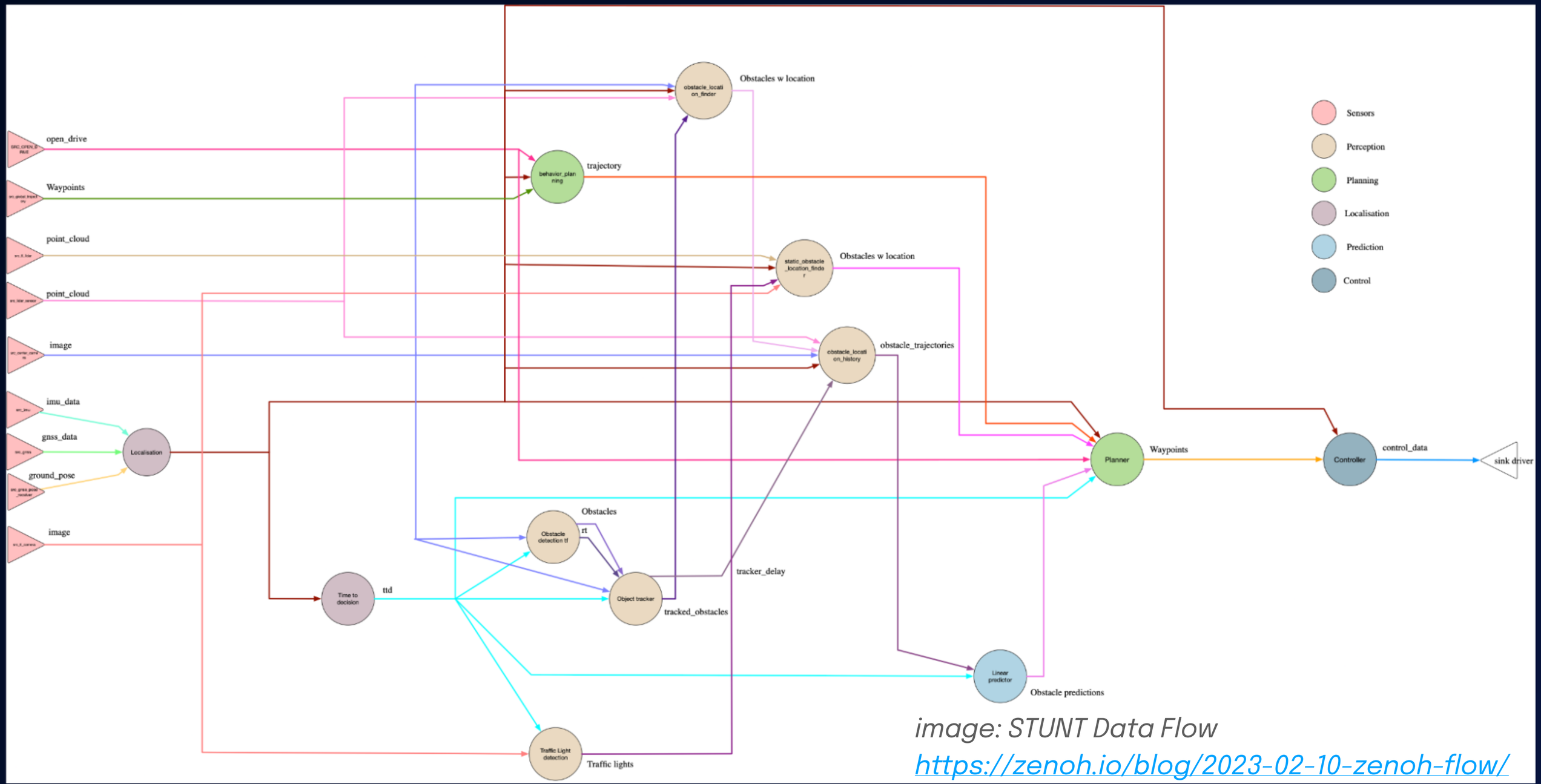


image: STUNT Data Flow
https://zenoh.io/blog/2023-02-10-zenoh-flow/

What’s the common point ?

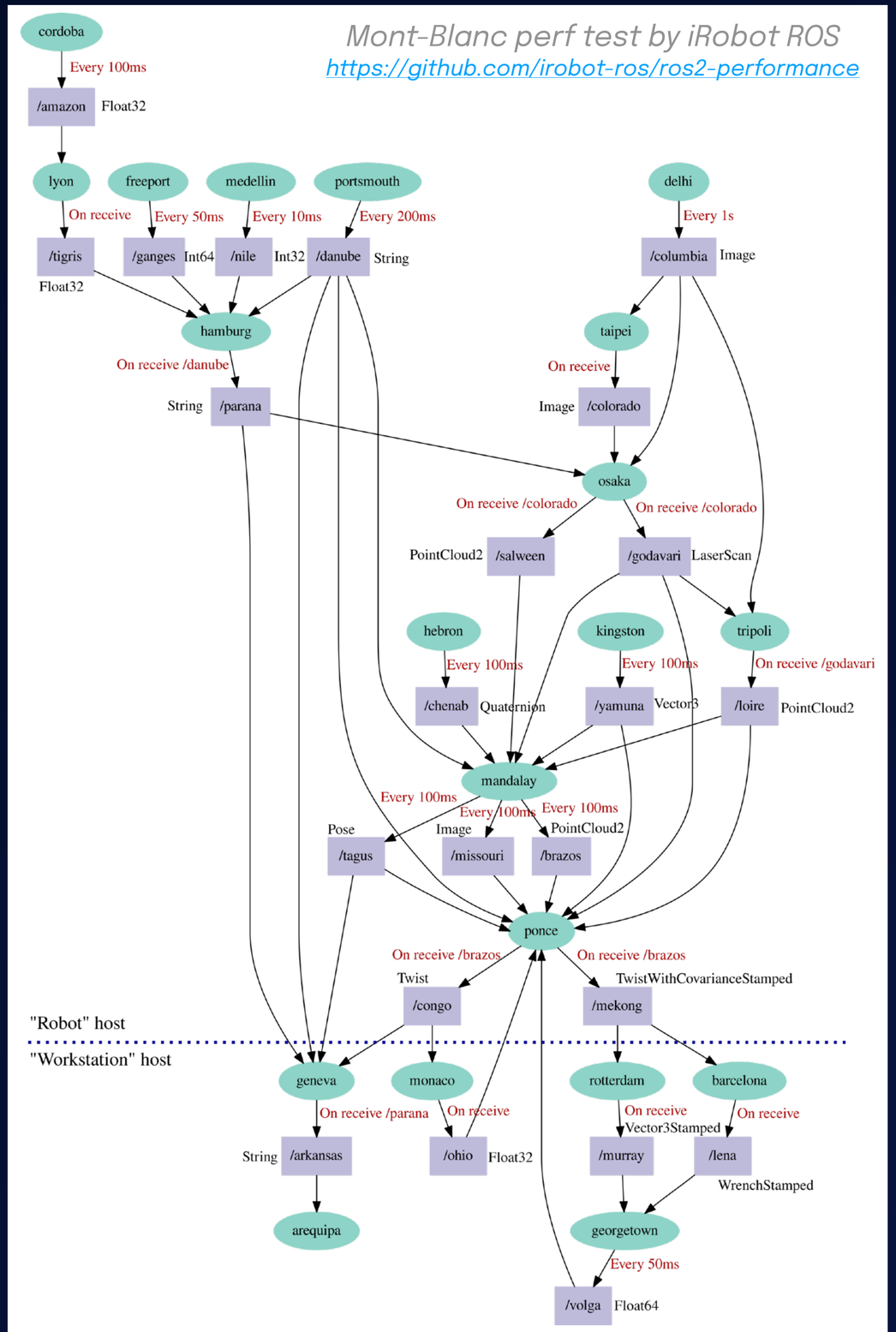
Modular architectures with multiple software components.

Benefits:

- Code reusability, faster development
- Easier testing, improved quality
- Improved maintenance and evolution
- Scalability and dynamism
- Improved fault tolerance

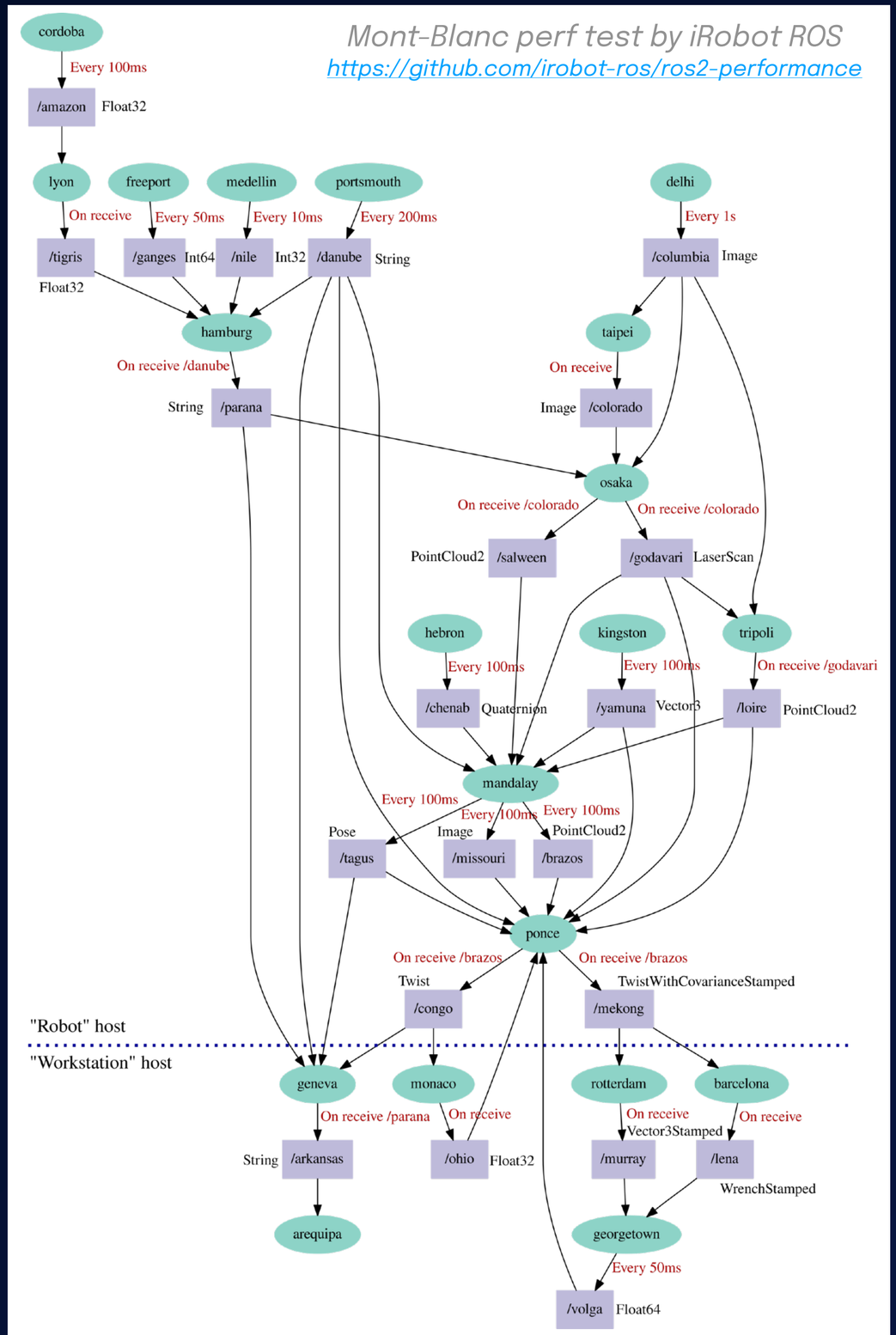
Which communication patterns ?

- **Pub / Sub**
  - 1-to-1 or 1-to-many
  - Asynchronous
- **Service call**
  - 1-to-1 (or 1-to-many ?)
  - Synchronous, 1 reply
- **Mission/Action call**
  - 1-to-1 (or 1-to-many ?)
  - Asynchronous, 1 or many replies (feedbacks)



Which deployment ?
Which communication transport ?

- **Process co-localisation**
  - Function calls, messages queues…
- **Host co-localisation**
  - Shared-Memory, Unix Pipes, loopback…
- **Multi-boards**
  - Ethernet, Serial, CAN bus…
- **Multi-hosts**
  - Ethernet, WiFi, 4G/5G, bluetooth…



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Which middleware(s) ?

DDS

MQTT

gRPC

TCP

ØMQ

UDP

Shared Memory

Introducing Eclipse Zenoh

https://github.com/eclipse-zenoh/zenoh

Open Source & Open Governance

Zenoh is an Eclipse Foundation Project

This ensures open, transparent and meritocratic governance

The eclipse foundation release process ensures strong guarantees on IP, Licensing and provenance

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Zenoh

Pub/Sub/Query protocol that **Unifies data** in **motion**, data at **rest** and **computations** from embedded microcontrollers up the data centre

Provides **location-transparent** abstractions for **high performance pub/sub** and **distributed queries** across heterogeneous systems

Built-in support for zero-copy and shared memory

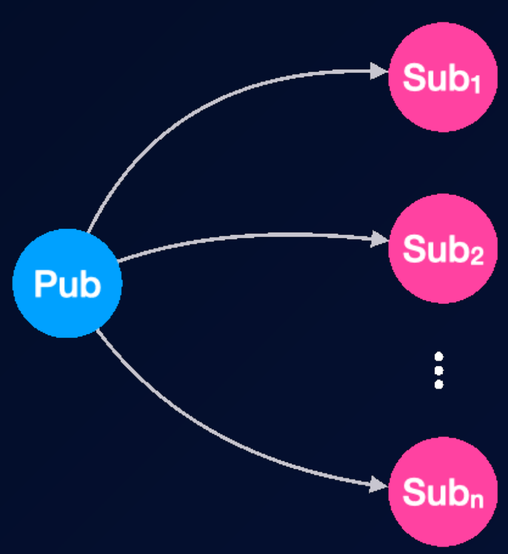
What does this Mean?

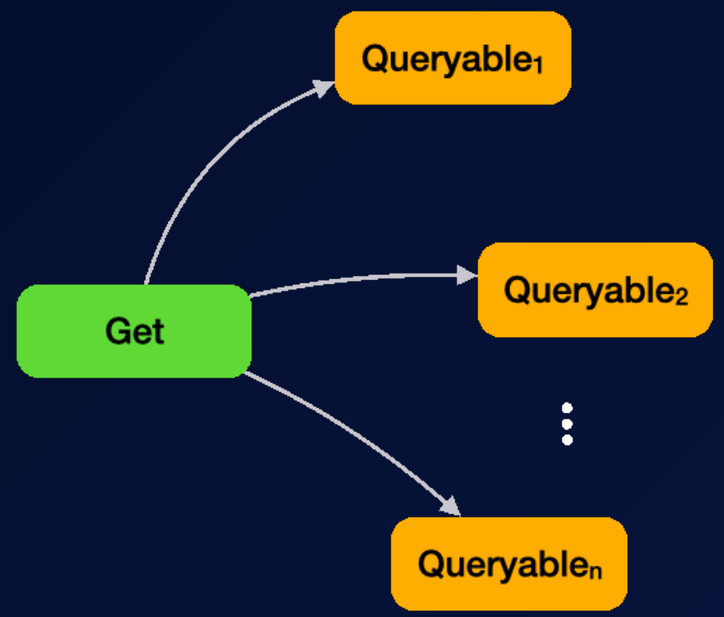
Zenoh's Primitives

Zenoh is built upon **two primitives** operating on **named data**: **pub/sub** and **query/reply**

Named data is represented by as (key, value) tuple, *e.g.*, (`bot-1/sensor/speed`, `25`)

These two orthogonal primitives allow Zenoh to efficiently deal with distributed computations, data/event dissemination and storage

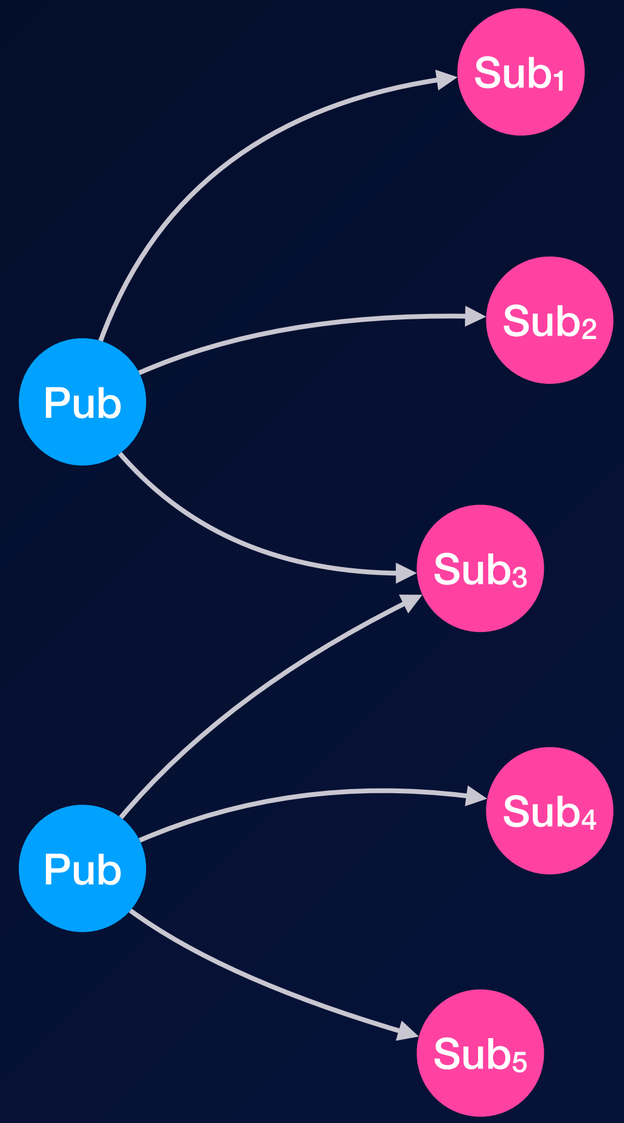




Pub/Sub Cont

Zenoh matching is based on key expressions

A subscriber has associated a key expression and will receive all publications with a matching key

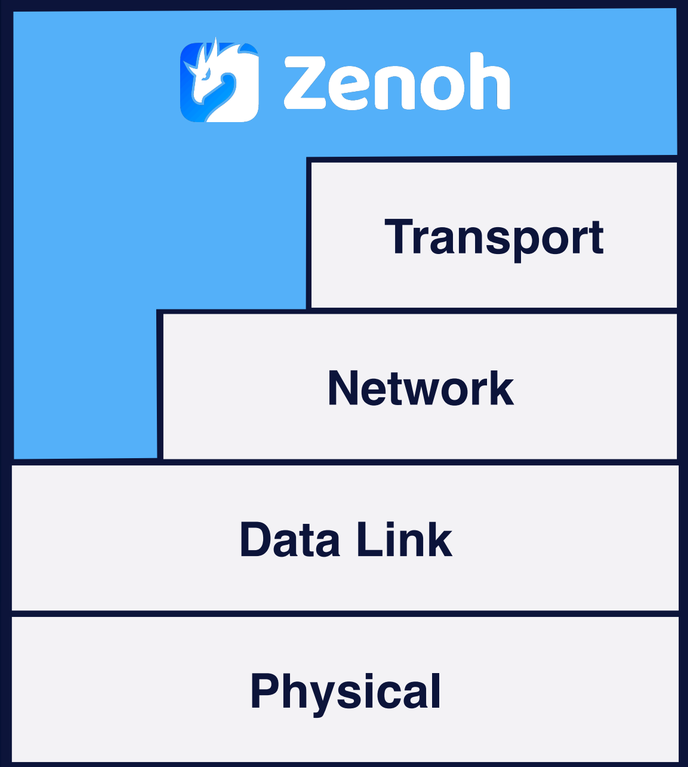


Protocol Stack

Zenoh was designed to be able to run on Data Link or higher in the networking stack

Supports **network technologies** from **transport layer down-to** the **data link.** Currently runs on, TCP/IP, UDP/IP, QUIC, Serial, Bluetooth, OpenThreadX, Unix Sockets, Shared Memory

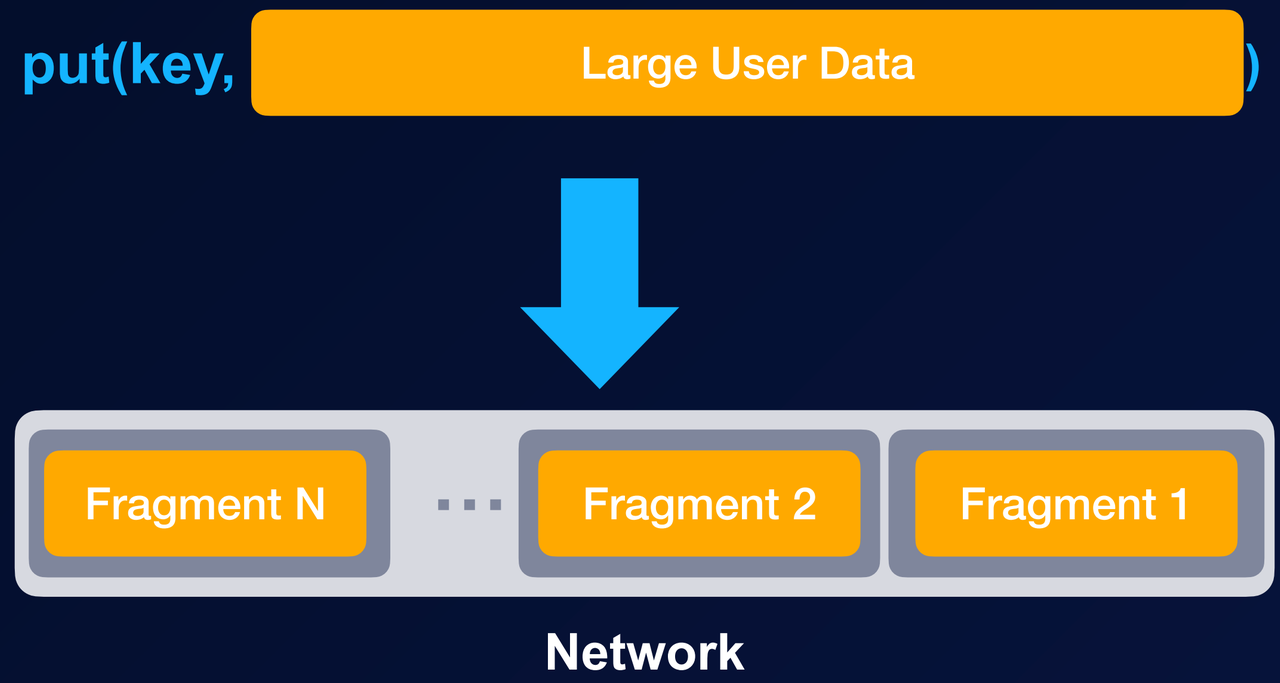
The protocol available on **embedded** and **extremely constrained devices** and **networks –** 6 bytes minimal overhead



Automatic Fragmentation

Zenoh automatically splits large user payloads in smaller messages to:

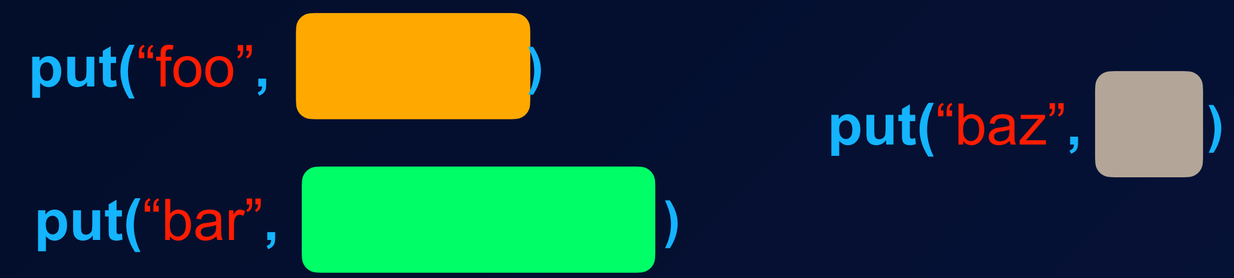
- Adapt to network MTU
- Bound head of line blocking

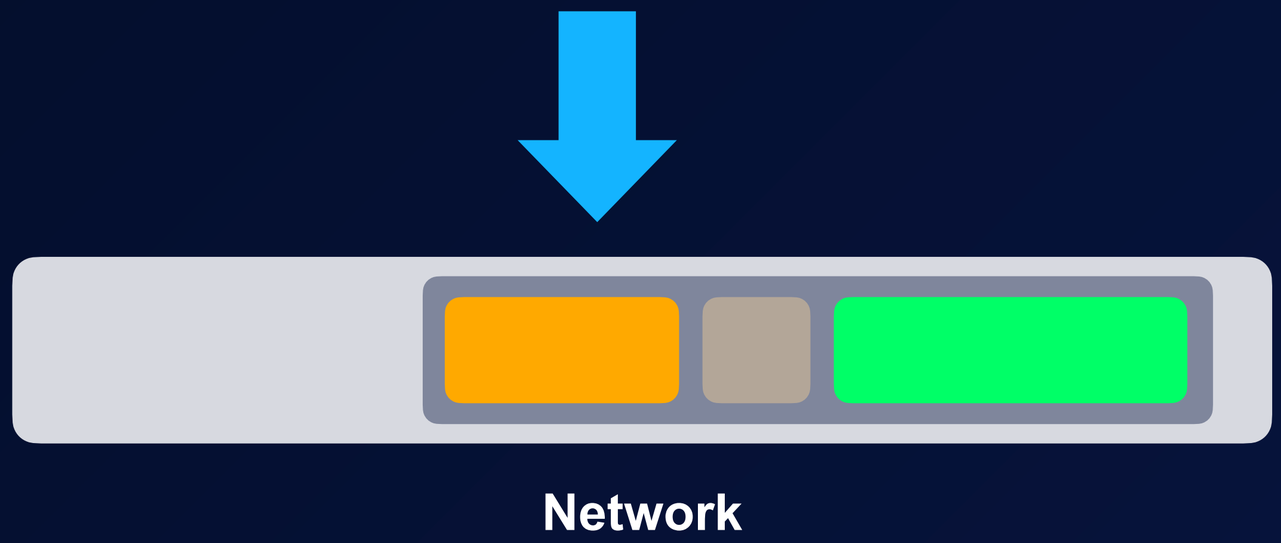


Automatic Batching

Zenoh automatically batches messages to:

- Improve Throughput
- Reduce Network Overheard
- Reduce CPU utilisation





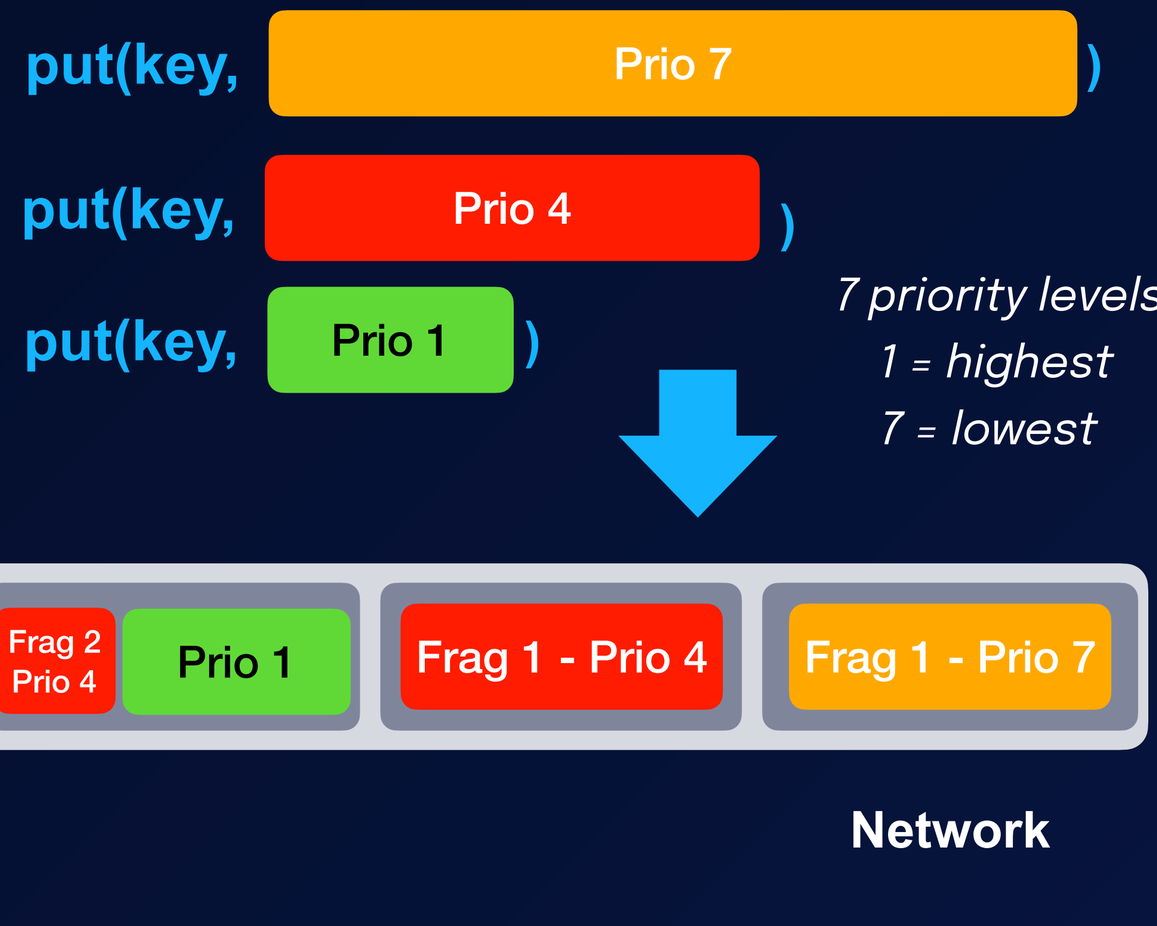
Optionally: **Express** publication to bypass the batching !

Priority Network Scheduling

Zenoh has building support for priority-based network scheduling

Within a session priority inversion is only bounded by time to send a fragment.

This allows interleaving of messages and avoidance of head of line blocking.

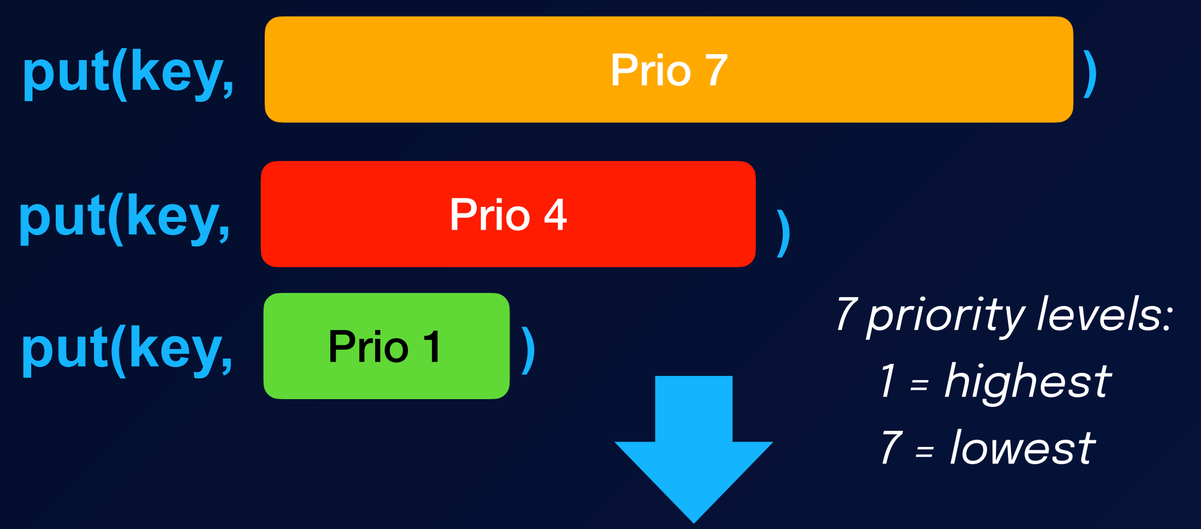


Multi-links

Zenoh supports multiple links between peers and routers.

Each link can be configured with a range of priorities.

Allowing to segregate different priorities on separate network sessions

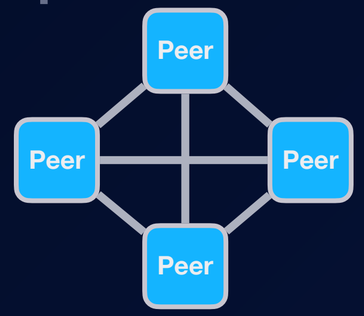


Any Topology

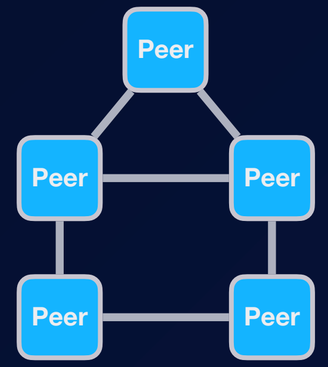
Peer-to-peer

Clique and mesh topologies

Clique



Mesh

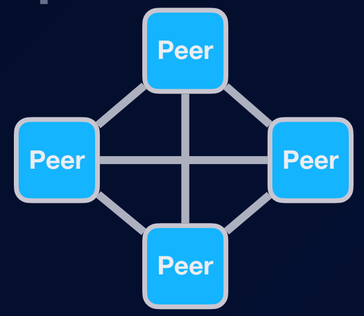


Any Topology

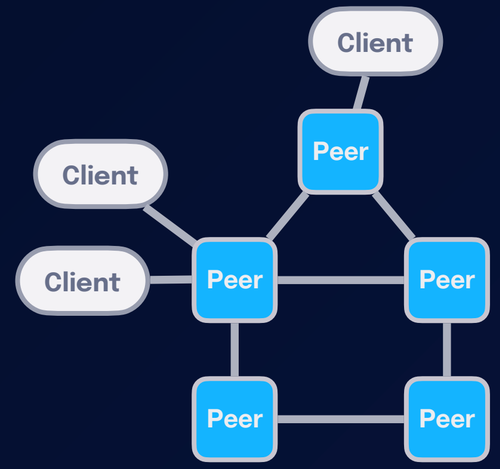
Peer-to-peer

Clique and mesh topologies

Clique



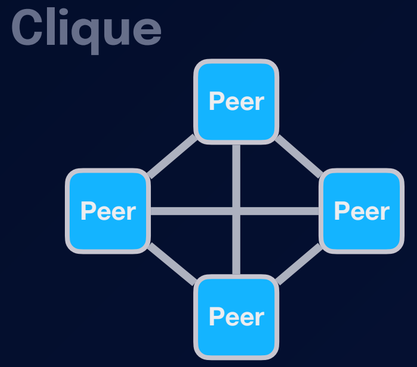
Mesh

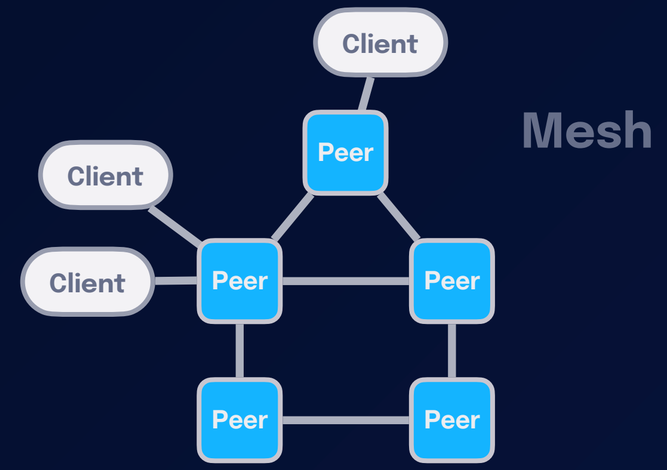


Any Topology

Peer-to-peer

Clique and mesh topologies

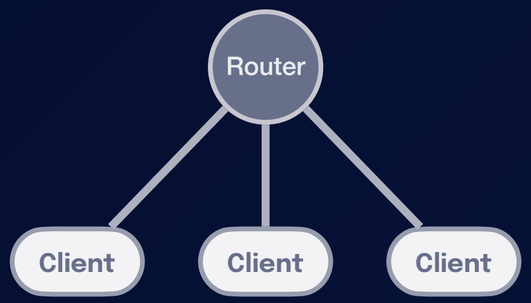


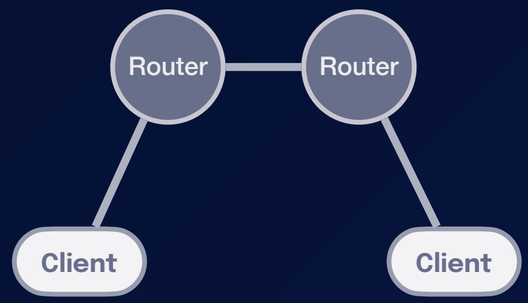


Brokered

Clients communicate

through a router or a peer





Any Topology

Peer-to-peer

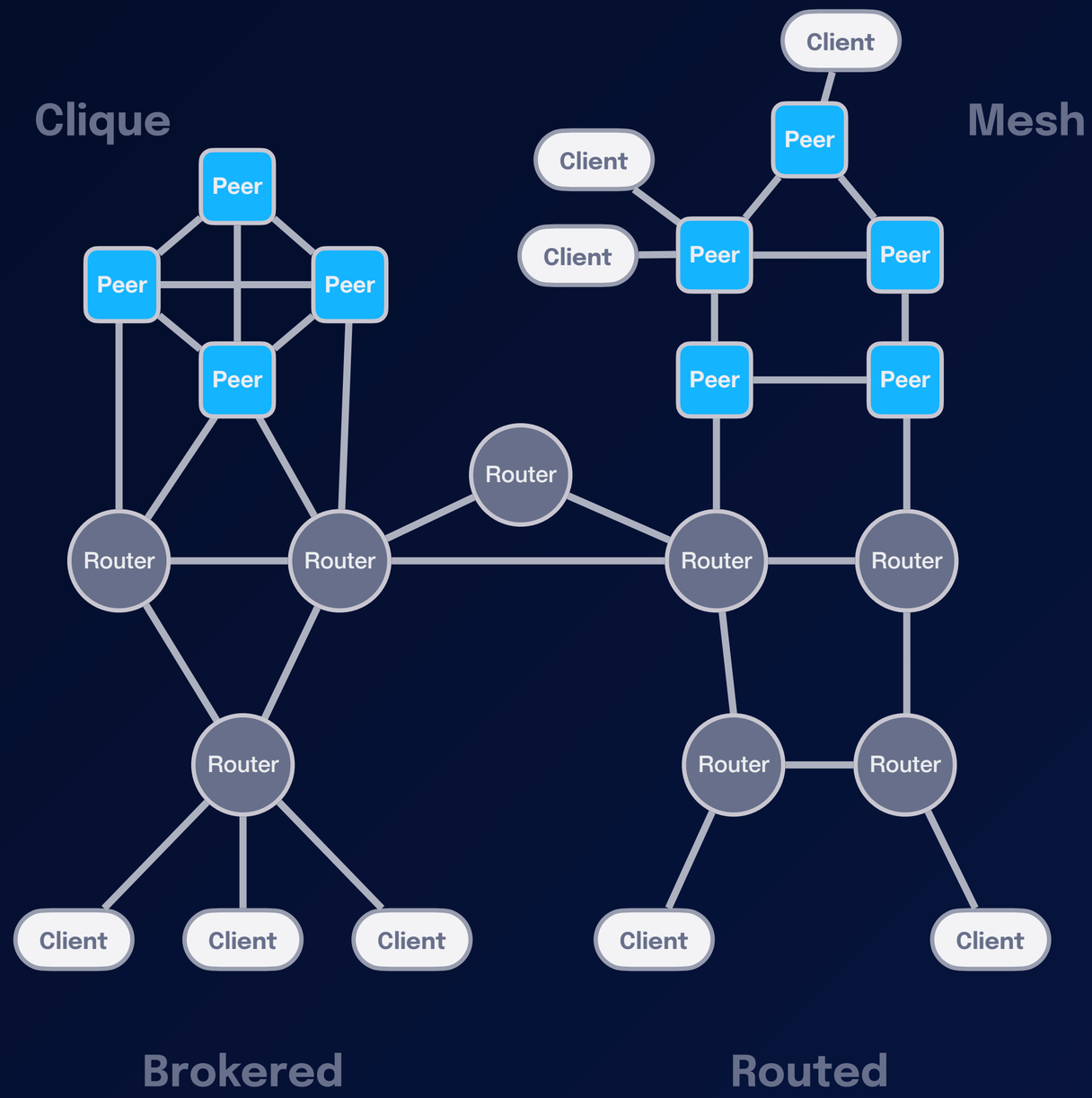
Clique and mesh topologies

Brokered

Clients communicate
through a router or a peer

Routed

Routers forward data to and
from peers and clients



Zenoh Implementations

ZettaScale leads two implementations of the Zenoh protocol

Zenoh written in Rust and **Zenoh Pico** written in C and targeting micro-controllers

When using C/C++ APIs, applications can target either of these versions – it is a compile-time decision

Used in ROS 2, but not only

ROS 2 - RMW Zenoh

- Available for Jazzy, Tier 1 for Kilted (May'25)
  https://github.com/ros2/rmw_zenoh

Hephaestus

- C++ robotic framework based on Zenoh
  https://github.com/olympus-robotics/hephaestus

Dora

- Dataflow-Oriented Robotic Architecture, using Zenoh for pub/sub
  https://github.com/dora-rs/dora

Copper - coming soon

- Rust-native software engine for robotics.
  Roadmap: *"Implement Zenoh to allow a swarm of robots"*
  https://github.com/copper-project/copper-rs

Zenoh Flow

- Rust-native declarative data-flow programming framework
  https://github.com/eclipse-zenoh-flow/zenoh-flow

ICOS

Towards a functional continuum operating system

ICOS project has received funding from the European Union's Horizon Europe Framework Programme under the Grant Agreement N° 101070177.

EcoMobility

Intelligent, Safe & secure connected Electrical Mobility solutions: Towards European Green Deal & Seamless Mobility

EcoMobility has received funding from Chips Joint Undertaking (Chips JU) under Grant Agreement No 101096387. Co-funded by European Union.

EMPYREAN

Trustworthy, Cognitive and AI-Driven Collaborative associations of IoT devices and edge resources for data processing

EMPYREAN research project has received funding from the European Union's HORIZON Europe under the Grant Agreement n° 101136024.

EdgeAI-Trust

Decentralized Edge Intelligence: Advancing Trust, Safety, and Sustainability in Europe

EdgeAI-Trust "Decentralized Edge Intelligence: Advancing Trust, Safety, and Sustainability in Europe" project has received funding from Chips Joint Undertaking (Chips JU) under Grant Agreement No 101139892-2.

O-CEI

O-CEI Open CloudEdgeIoT Platform Uptake in Large Scale Cross-Domain Pilots

O-CEI project has received funding from the European Union's Horizon Europe Framework Programme under the Grant Agreement N° 101189589.

Funded by the European Union

Chips JU

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Thank You

Patience, persistence and perspiration make an unbeatable combination for success.