Separation of Data Path and Data Flow Sublayers in the Transport Layer

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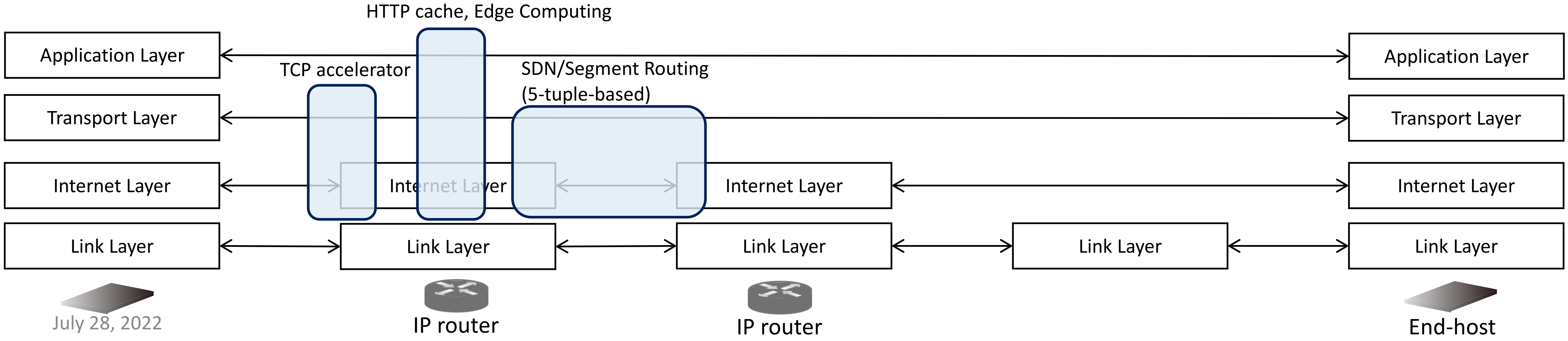
Motivation: Reconsider the Internet Architecture for Future Protocol Development

- End-to-End Principle
  - “Dumb” network with smart end-hosts
- Smarter networks break RFC 1122 & 1123 layering model.
  - QoS (e.g., DiffServ, ECN, Segment Routing)
  - Middlebox (e.g., Firewall, Content caching, Transcoding, TCP acceleration)
  - New distributed computing paradigm (e.g., Pub/sub model for machine-to-machine communication, Edge computing, In-network computing)



Gap Analysis between IP Routing and Transport Layer Protocols

- IP routing
  - Hop-by-hop store-and-forward with a single or multiple queues
- Transport layer protocols
  - End-to-End functionality
    - Reliable data communication (integrity check, retransmission, etc.)
    - Flow control for receive buffer management
    - Transport layer security (TLs)
  - Path-dependent (soft dependent) functionality; with observation from endhosts
    - MTU discovery (ICMP)
      - MTU may not be consistent if the path is changed.
    - Congestion control / Explicit congestion notification (ECN)
      - Bandwidth capacity and congestion may change on path changes.
  - Waypoint-dependent middleboxes; with a gateway or policy-based routing.
    - Firewall (stateful)
    - NAT (NAPT)
    - Transparent proxy (content caching, transcoding, etc.)
    - TCP accelerator

More path-aware communications

- Multipath protocols
  - SCTP, MP-TCP, MP-QUIC, MP-DCCP, etc…
- AQM-aware congestion control (e.g., L4S)
- Pub/sub-based M2M communication
- Edge computing
- Network slicing
- In-network computing / In-network telemetry
- …

emerging with net programmability

Problems with Transport Layer Protocols

- Tightly-coupled design of transport layer protocols
  - All components of transport layer functionality are integrated to one protocol.
    - e.g., multipath protocols are developed for each transport layer protocols.
      - SCTP, MP-TCP, MP-QUIC, MP-DCCP

→ Hard to develop both "IP-friendly" and "transport-layer-friendly" network extensions.

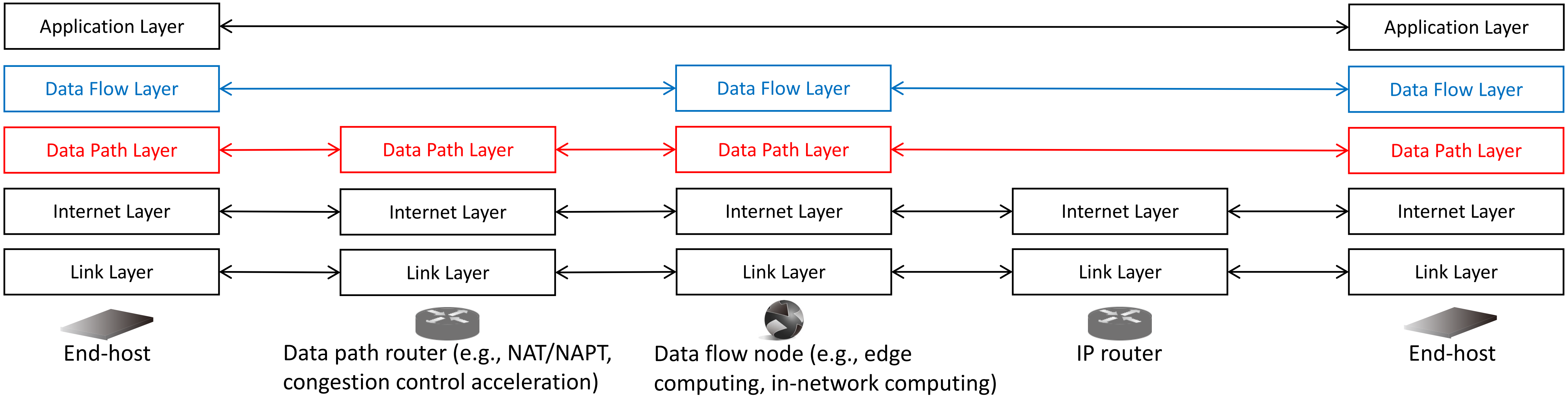
Reviewing Transport Layer Functionality: Data Path vs. Data Flow

- Data Path → Stateless or per-path states
  - Trajectory & waypoint handling
  - Bidirectional connection
  - Resource monitoring (e.g., congestion monitoring like ECN or in-network telemetry)
  - Congestion control
  - Data flow multiplexing
  - Packet duplication for packet loss recovery (like FEC or detnet replication)
- Data Flow → Per-flow states
  - Retransmission for reliable data communication
  - Flow control (buffer management)
  - Flow prioritization
  - End-to-end security
  - Inverse multiplexing for multipath protocols

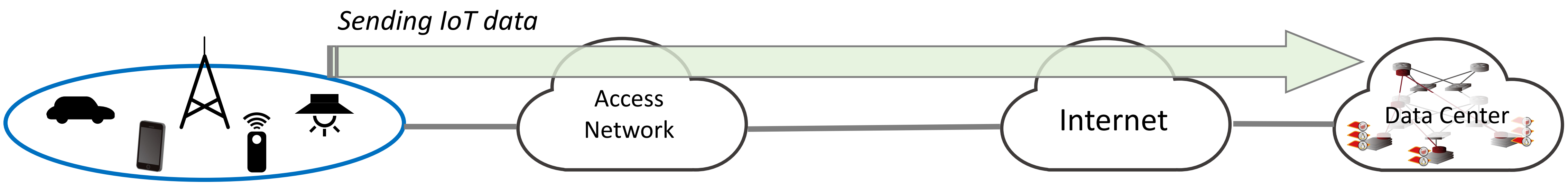
Proposal: Data Path and Data Flow Sublayers

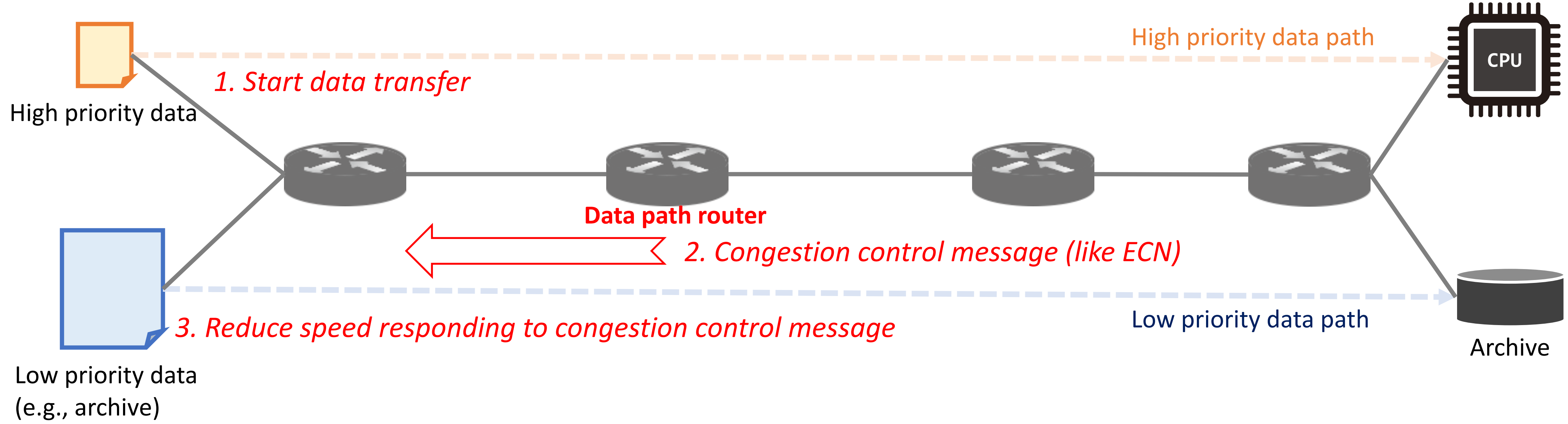
(may update RFC 1122, 1123)

- Data flow layer: Retransmission, flow control, flow prioritization, end-to-end security, inverse multiplexing (over multiple data paths)
- Data path layer: In-band trajectory monitoring, waypoint management, bidirectional connection, quality monitoring, congestion control, data flow multiplexing, duplication

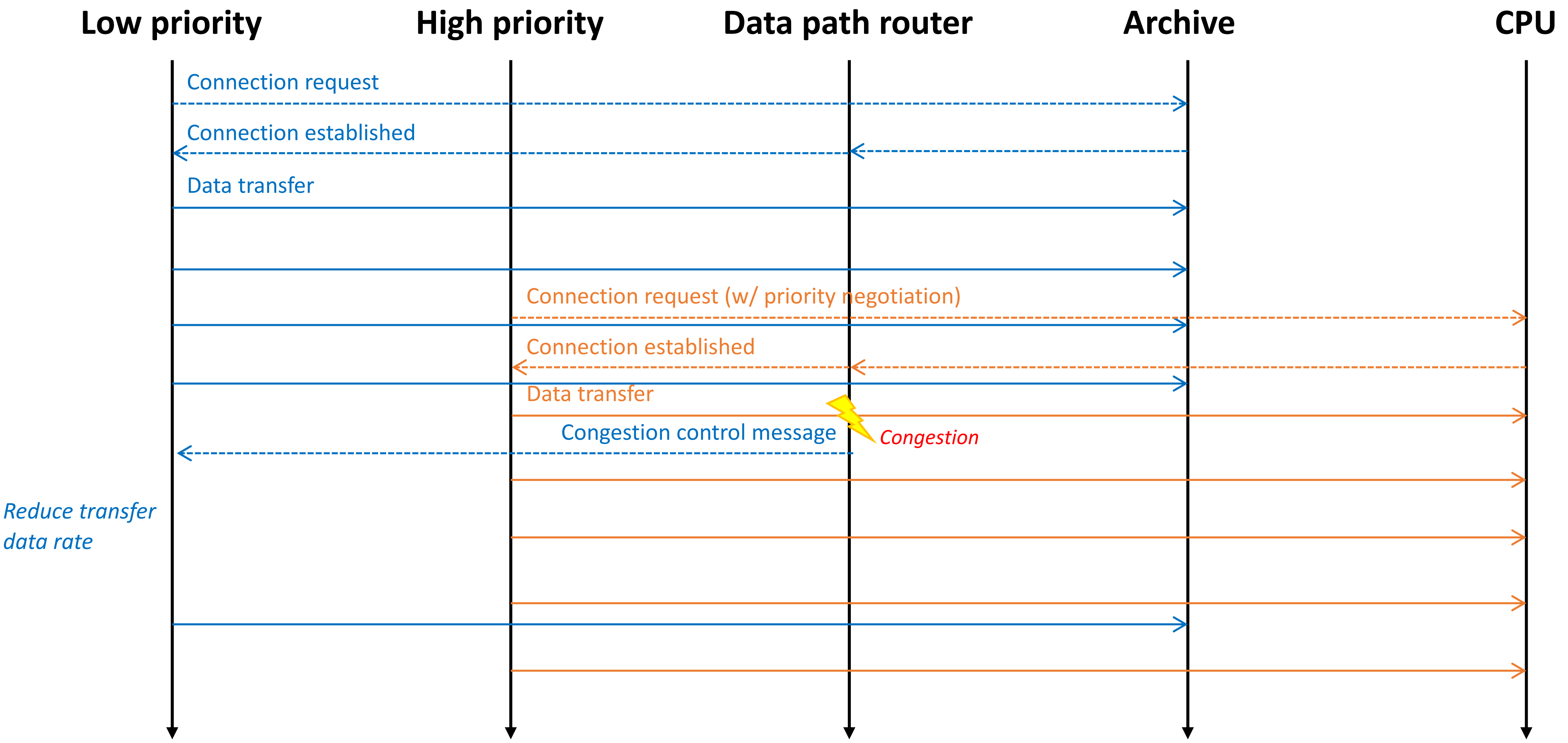


Use Case: Flow Arbitration in IoT





Use Case: Flow Arbitration in IoT (cont'd)



N.B. This scenario could be achieved with TCP, ECN and DSCP as the data path functionality is limited.

Next Step

- As research:
  - Discuss the gap between hop-by-hop and end-to-end from the viewpoint of data path and data flow
  - Review existing transport layer protocol functionality
  - Architect for new communication models of distributed computing
    - Pub/Sub-based machine-to-machine communication
    - Multiaccess edge computing
    - In-network computing
- As protocol development:
  - Design an example of data path and data flow protocol