Bridging the ICN Deployment Gap with IPoC

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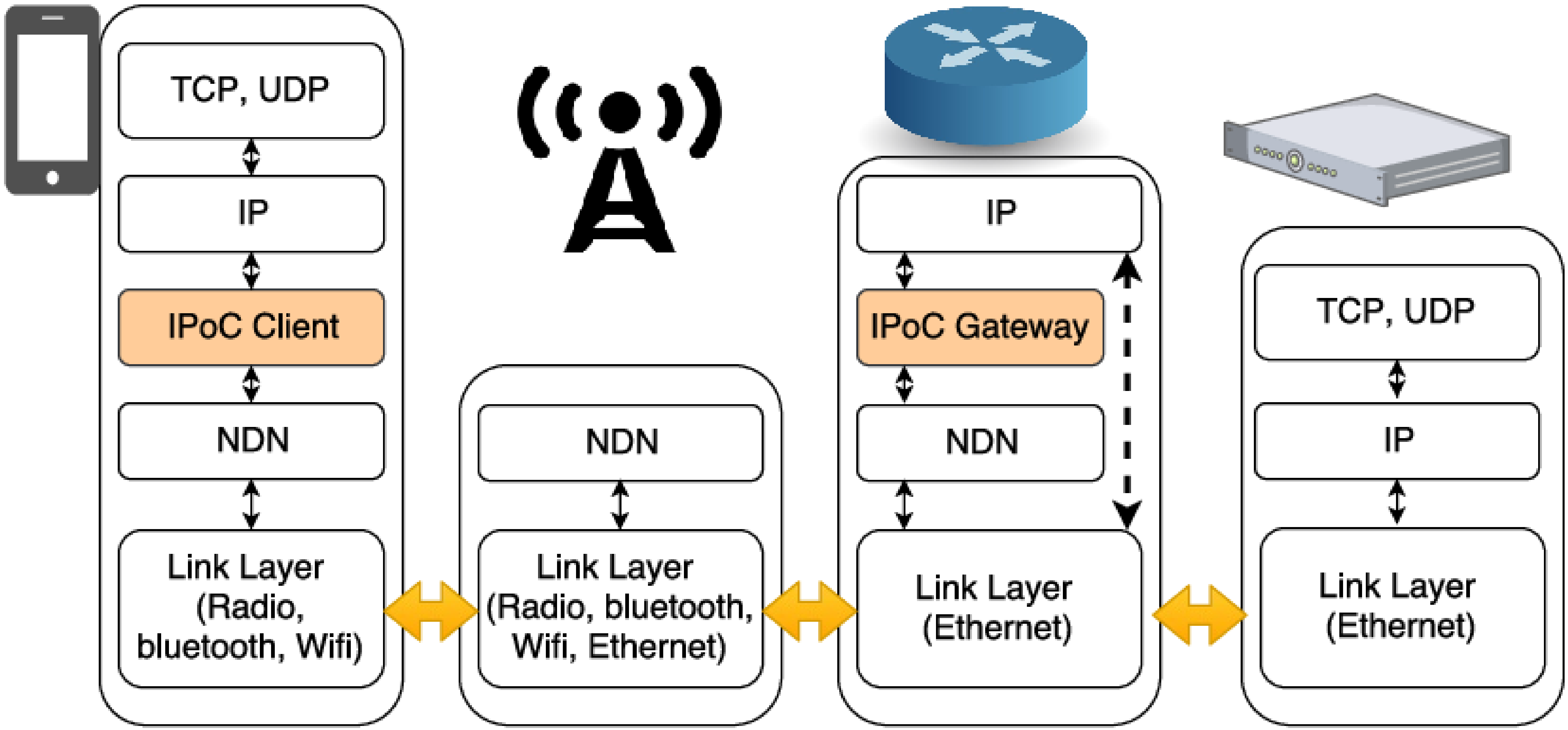
Background

- ICN seems attractive for mobile networking
  - Elegant consumer mobility via stateful forwarding
  - Multipath connectivity managed by the mobile device
  - In-network caching and processing
- How do we get there?
  - Network slicing? – and run two networks in parallel?
  - ICN over IP? – and lose the benefits above?

Concept

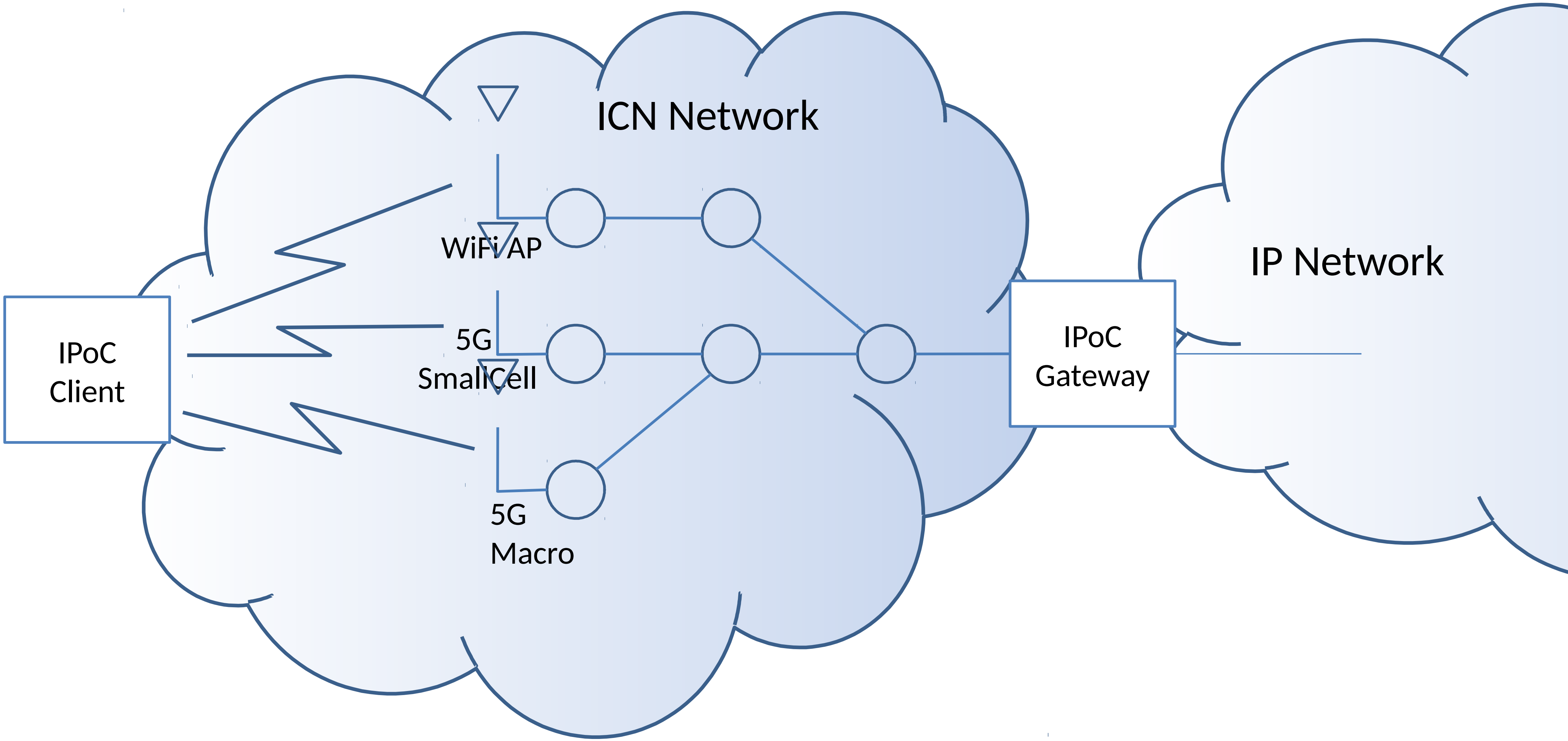
- Explore the idea of using ICN as THE forwarding plane for 5G
- **Support ALL existing IP services** via an “IP over ICN” protocol – replacing LTE-EPC (GTP Tunnels) for IP Mobility
- Enable deployment of native ICN applications, preserving the benefits


TCP, UDP
IP
IPoC Client
NDN
Link Layer (Radio, bluetooth, Wifi)
NDN
Link Layer (Radio, bluetooth, Wifi, Ethernet)
IP
IPoC Gateway
NDN
Link Layer (Ethernet)
TCP, UDP
IP
Link Layer (Ethernet)

IP over ICN (IPoC) Goals

- Support all existing IP applications & transports without modification
  - Incl. TCP, UDP, SCTP, DCTCP, QUIC, BBR, etc.
  - …maybe not IP multicast.
- No change to IP stacks
- Leverage consumer mobility of ICN
- Support multipath connectivity
- High performance
- Low overhead
- Be a compelling replacement for EPC

Architecture

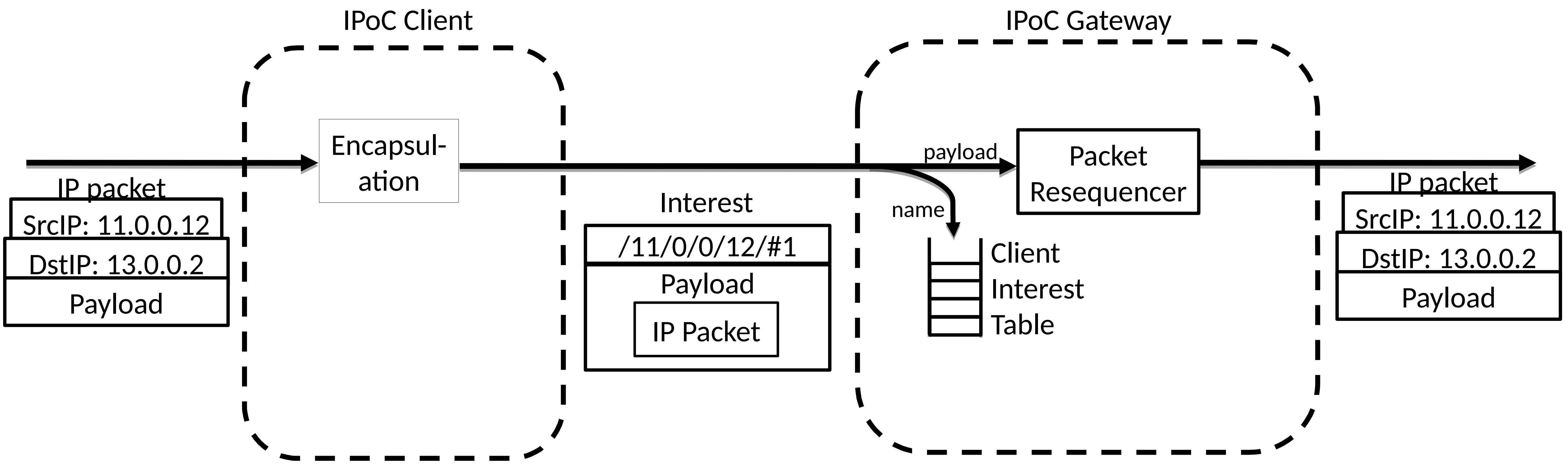


Leverage consumer mobility

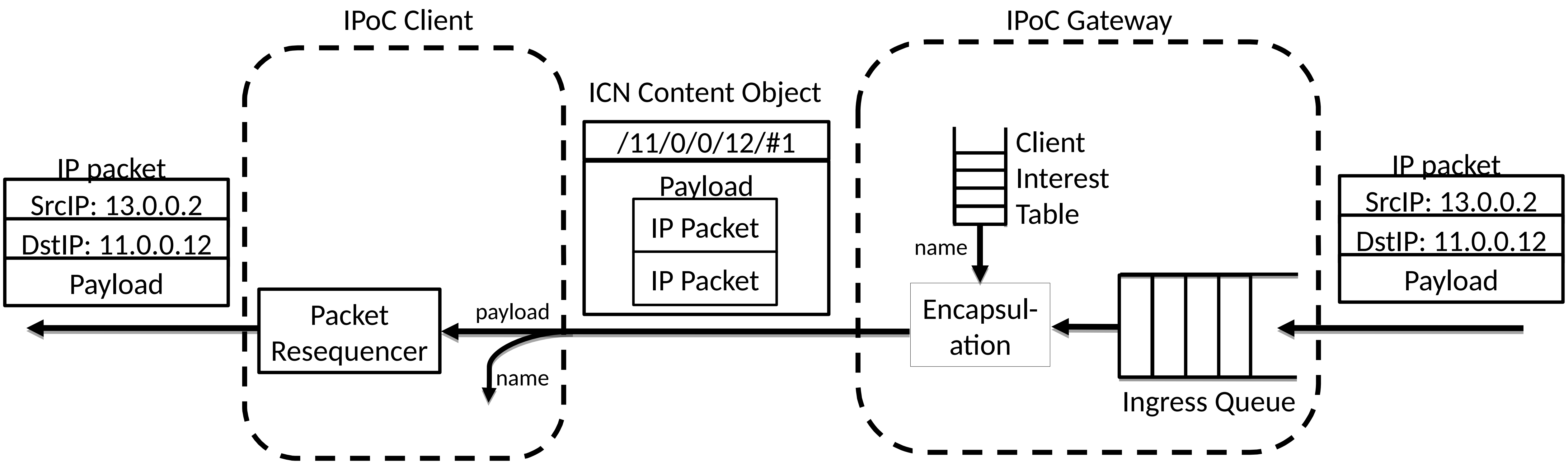
- IPoC Client only sends Interest messages
  - “upstream” IP packets carried as Interest payloads

- IPoC Gateway only sends Content Objects
  - Containing “downstream” IP packets as payloads

“Upstream” (UE->Network) Packet Flow



“Downstream” (Network->UE) Packet Flow



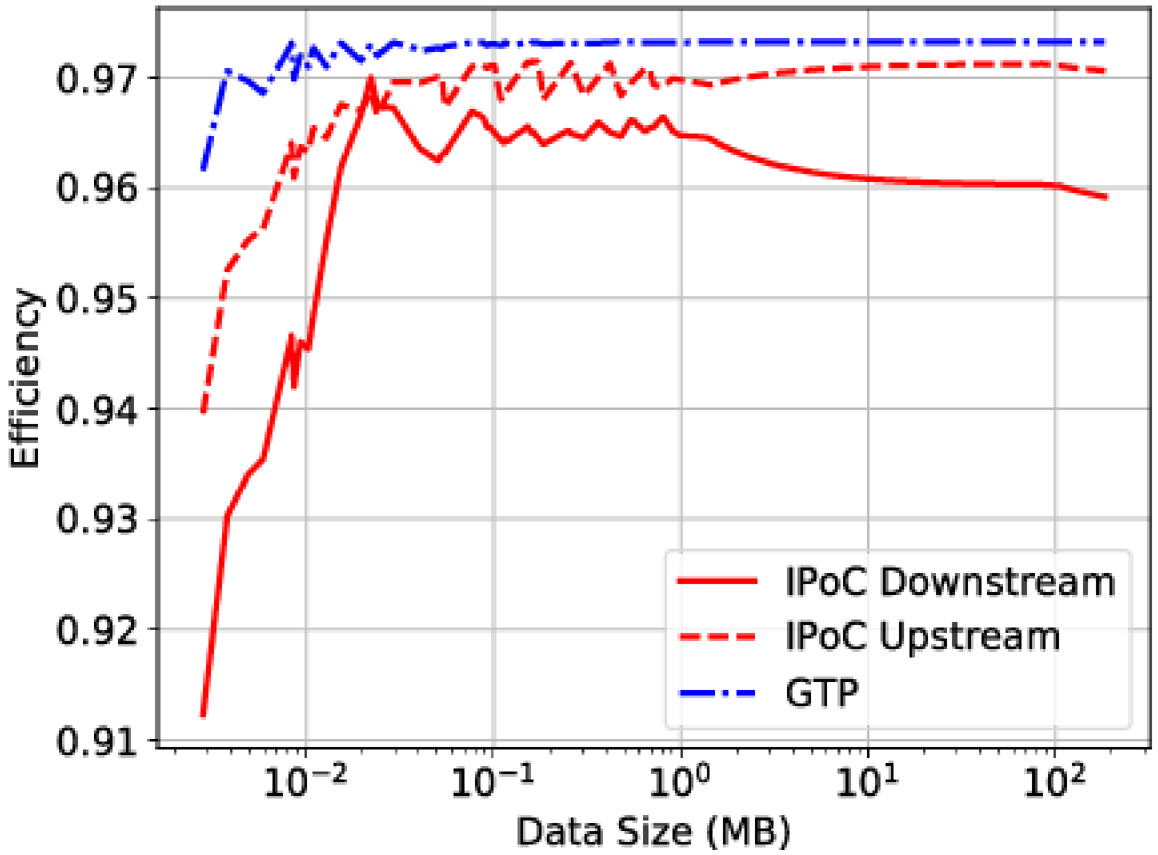
IPoC Naming Convention

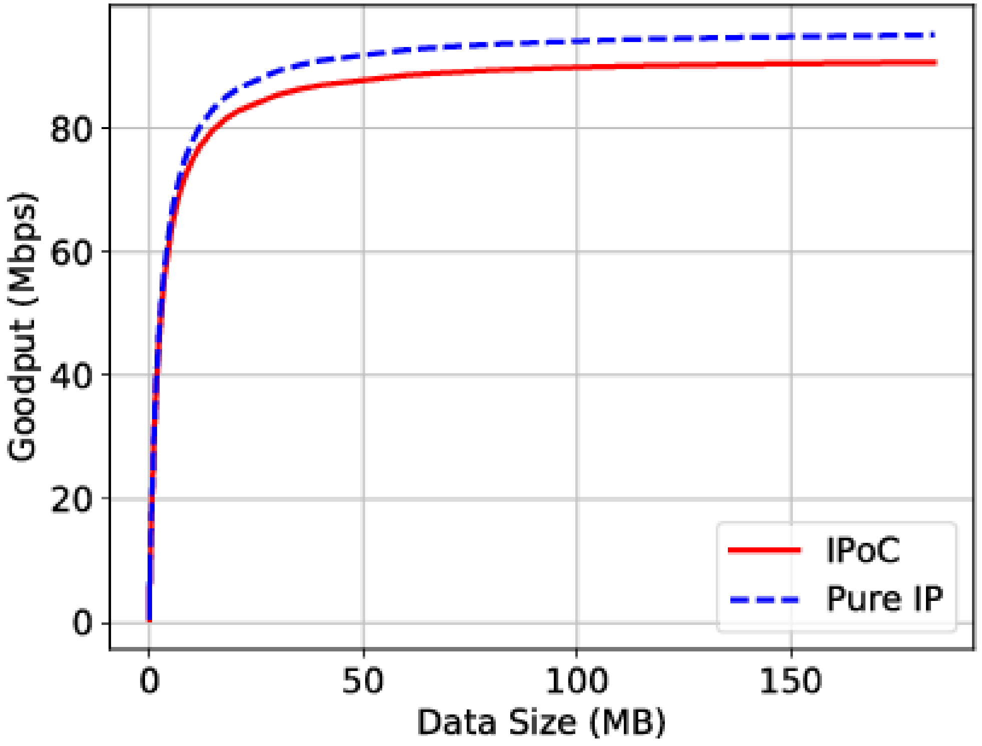
- `ndn:/ipoc/<hex_ipaddr>/<b64_seq>`
- `hex_ipaddr:` Client IP address
- `b64_seq:` Interest Sequence Number
  - base64-encoded, monotonically increasing (with rollover)

Managing In-flight Count and Flow balance

- Gateway sends IDR to the client with each content
  - Interest Deficit Report included in Content Object
  - Allowed IDR values: -1, 0, 1
  - Client adds IDR value to its Interest Deficit Count

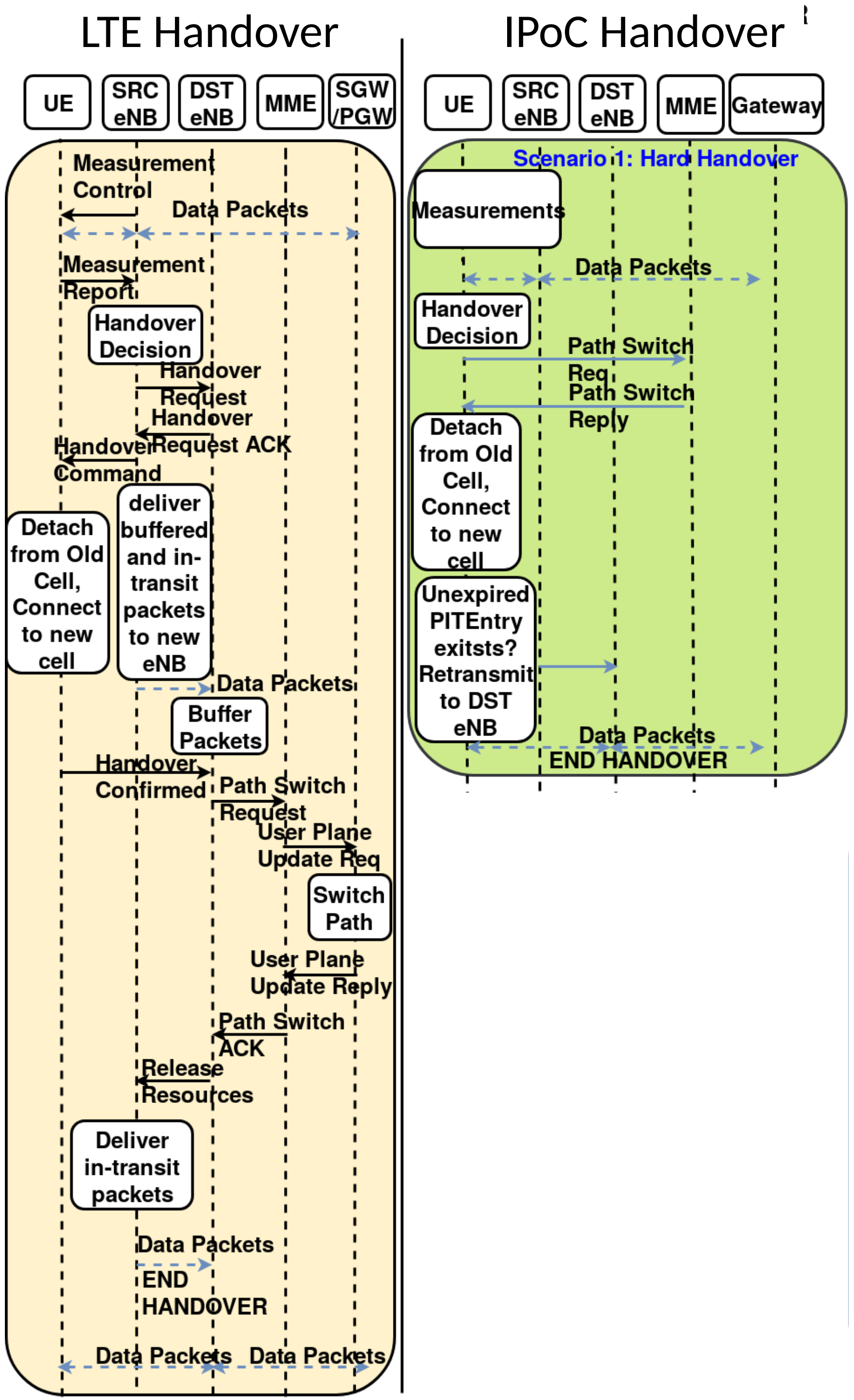
Evaluation – Efficiency and Throughput





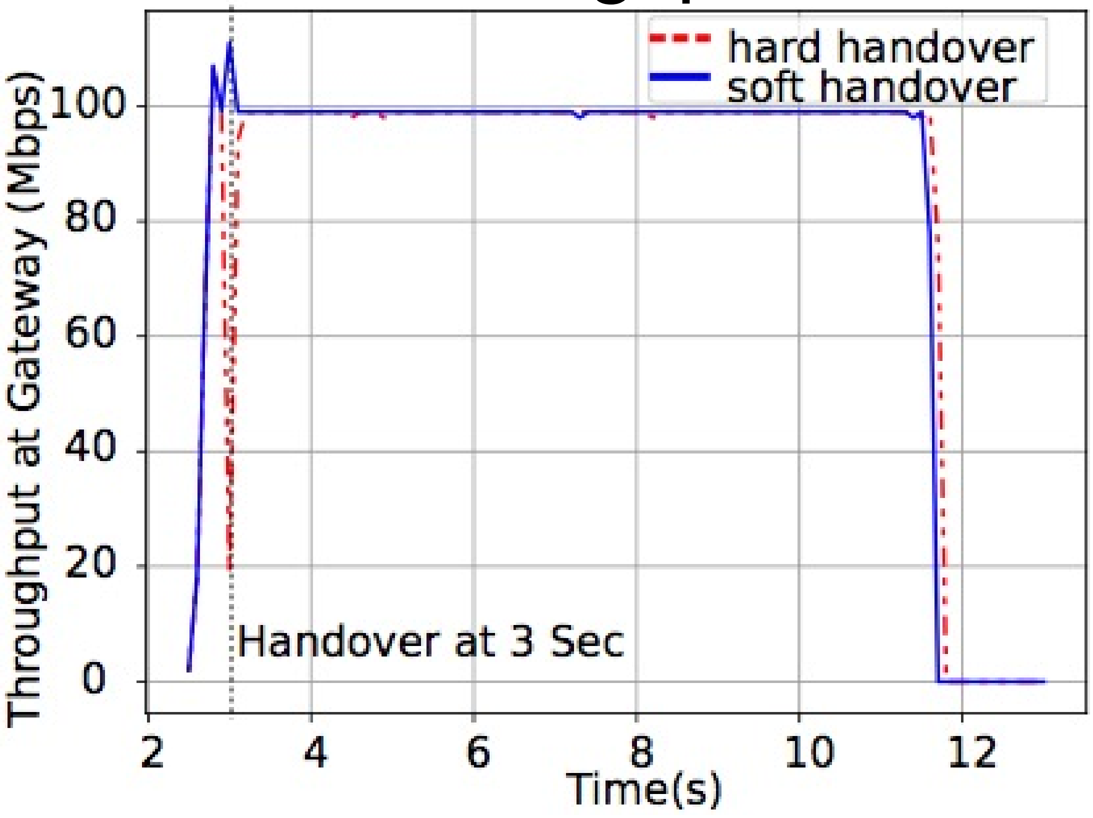
Reciprocal Benefits for 5G networks - LTE Handover vs. IPoC Handover

- IPoC significantly simplifies handover compared to LTE-EPC
- UE simply detaches from old link, establishes new link, and resends unexpired PIT entries (without payload).
- No handover-specific functions in GW, eNodeB/gNodeB, or network routers
- Soft handover & multipath connectivity are simple

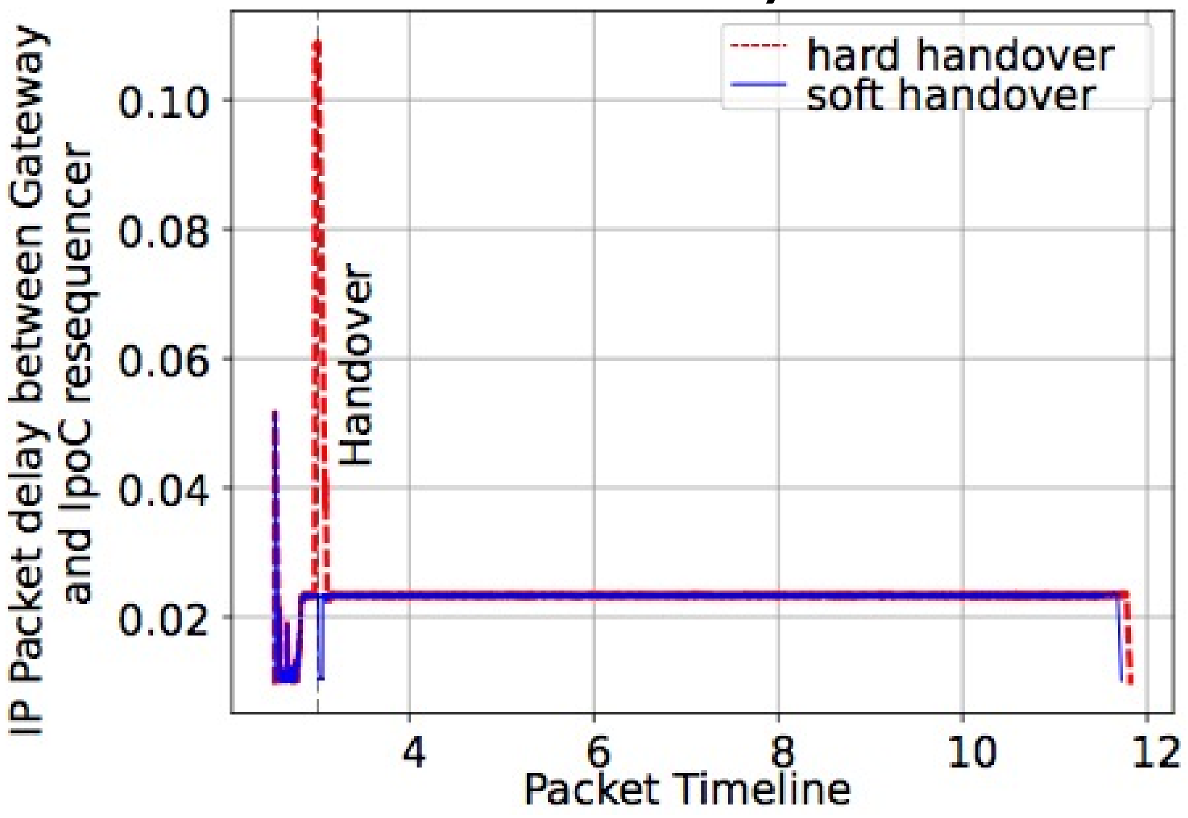


Hard vs Soft Handover Simulation

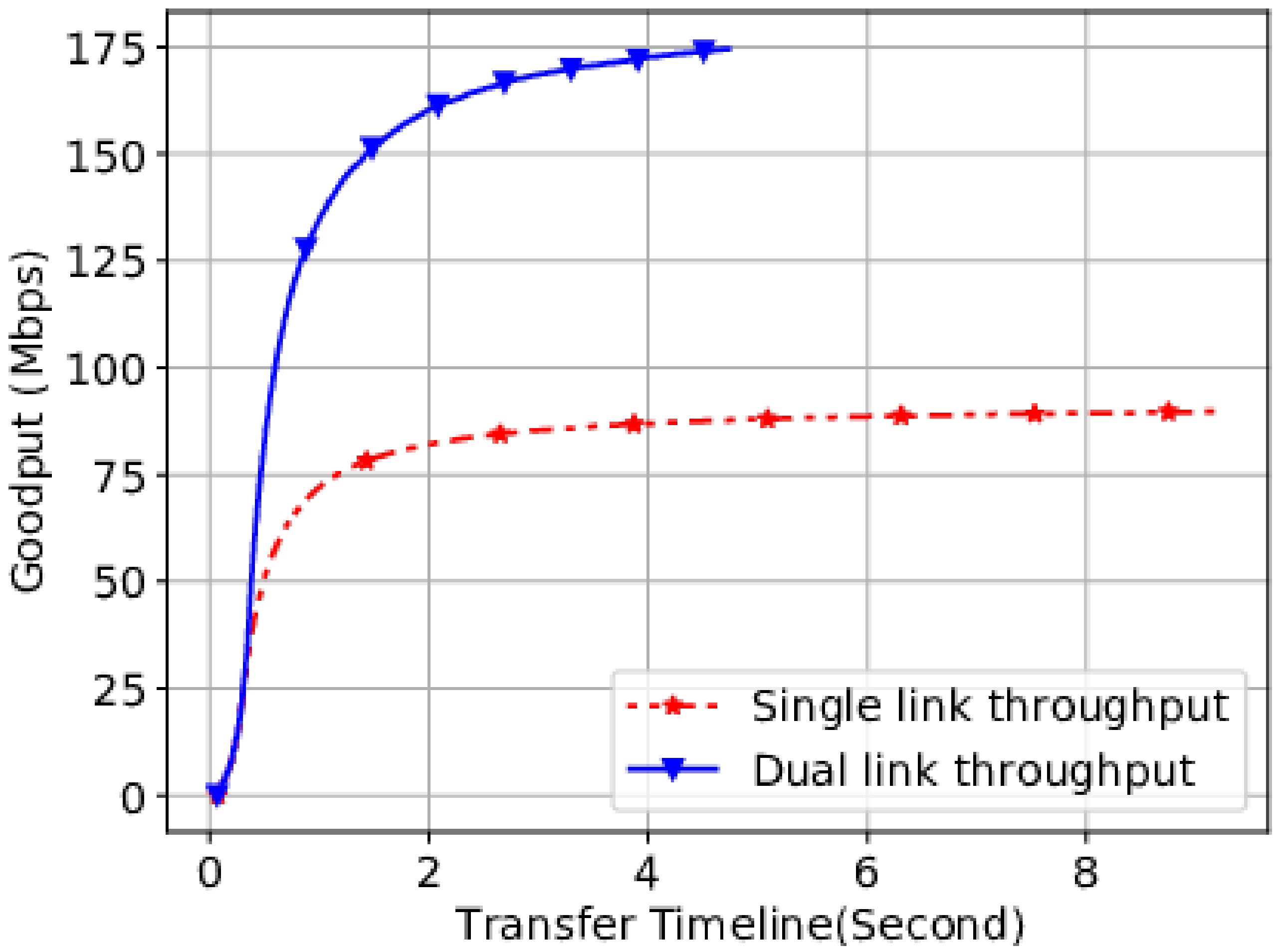
Throughput



Delay



Dual link – 5G/5G or 5G/WiFi



Implementations and future plans

- ndnSim implementation (ca. 2017)
  - Published at 2018 SIGCOMM NEAT
  - Soon to be be available in github
  - Possible NDN testbed deployment?

Questions and Comments?

“Upstream” IP packet handling

- Client: Upon receipt of one or more IP packets from the local stack:
  - Send an Interest message
    - Name formed by client’s IP address and next sequence number
    - Body contains entire IP packet(s)
- Gateway: Upon receipt of an Interest message
  - De-encapsulate IP packet(s) and add to resequencer for forwarding to IP network
    - Resequencer ensures in-order delivery
  - Add Sequence Number to the “Client Interest Table”

Client Interest Table (CIT)

- The CIT is a FIFO queue maintained by the gateway
- CIT contains received Interest Sequence Number and Arrival Time tuples
- One CIT per active client IP address

“Downstream” IP packet handling

- Gateway:
  - Arriving IP packets are queued on a per-client-IP basis*
  - Queues are serviced in a round-robin manner
  - Queue blocks when its CIT is empty
  - Packet(s) are dequeued to form a Content Object
  - CIT entry is dequeued to form CO name
  - CO includes a CO Sequence Number (monotonically increasing, with rollover)
    - CO Sequence Number space is independent of Interest Sequence Number space
- Client: Upon receipt of a Content Object
  - De-encapsulate IP packet(s) and add to resequencer for delivery to IP stack

*more sophisticated queuing, e.g. AQM/L4S could also be used