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
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

ICN Network

IPoC Client

WiFi/AP

5G SmallCell

5G Macro

IPoC Gateway

IP Network
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

IP packet
SrcIP: 11.0.0.12
DstIP: 13.0.0.2
Payload

Encapsulation

IPoC Client

Interest
/11/0/0/12/#1
Payload
IP Packet

Packet Resequencer

payload
name
Client
Interest
Table

IP packet
SrcIP: 11.0.0.12
DstIP: 13.0.0.2
Payload

IPoC Gateway
"Downstream" (Network->UE) Packet Flow

IPoC Client

Packet Resequencer

ICN Content Object

/11/0/0/12/#1

Payload

IP Packet

IP Packet

IPoC Gateway

Client Interest Table

Encapsulation

Ingress Queue

IP packet
SrcIP: 13.0.0.2
DstIP: 11.0.0.12
Payload

IP packet
SrcIP: 13.0.0.2
DstIP: 11.0.0.12
Payload
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

![Graphs showing efficiency and goodput vs data size](image-url)
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

![Graph showing dual link throughput compared to single link throughput over time. The x-axis represents the transfer timeline in seconds, and the y-axis represents goodput in Mbps. The graph includes two lines: a dotted red line for single link throughput and a solid blue line for dual link throughput.]
Implementations and future plans

- ndnSim implementation (ca. 2017)
  - Published at 2018 SIGCOMM NEAT
  - Soon to 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