CURLING: Content-Ubiquitous Resolution and Delivery Infrastructure for Next Generation Services

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• CURLING: An infrastructure to both accurately and efficiently \textit{hit} (or \textit{not hit}) content objects in specific regions / areas of the Internet.
  
  – The content resolution is natively \textit{coupled} with path setup.
  
  – Follows a domain-level \textit{hop-by-hop gossip-like communication model} without revealing explicit IP address pointing to the targeted content source
  
  – Content resolution driven by:
    
    • Business relationships among ISPs (provider/customer/peer)
    • BGP route
    • Content consumer preferences
    • ISP local policies
Entities in CURLING

Main entities:

- **Content Resolution and Mediation Entity (CRME)**
  - Resides in individual ISP
  - Collaboratively handles content publication requests, discovers requested content and supports content delivery

- **Content-aware Forwarding Entity (CAFE)**
  - Typically edge routers
  - Collaborates with local CRME to enforce content delivery paths
• Content lifecycle
  – Content publication
  – Content resolution
  – Content delivery
• Provider route forwarding rule
Content Publication

• Content publication – the process of making content available in the Internet

• **Stage 1**: Content registration
  – Content provider registers a new content (or a replica) to the local CRME
    • CP sends a `Register` message to the local CRME
      – with explicit location of the content (e.g., IP address of the content server)
      – And possibly with scoping option
    • Local CRME creates a new entry in the content management repository for the new content

• **Stage 2**: Content publication dissemination
  – Publish message dissemination strategy:

  **“Provider route forwarding rule”**
S1::Register(X1)

Publish(A.A, X1)

Publish(A.A.A, X1)

S1::Register(X1)
• Publication modes:
  – Wildcard mode
    • Content to be accessible to the entire Internet
    • Indicated by using an asterisk “*”
  – Scoped mode
    • Publication of content to specific areas in the Internet indicated by the content provider
      – E.g., BBC iPlayer are only available within UK
    • Indicated via the INCLUDE option in the Register/Publish messages
• **Content resolution** – the process of resolving a content consumption request (i.e., `Consume`) from a content consumer by:
  – Discovering the location(s) of the requested content and
  – Delivering the request to the actual content source to initiate content transmission

• **Stage 1**: Uphill resolution
  – The forwarding of the `Consume` request up along the provider route until it reaches a CRME that has the content record entry
  – `Consume` message dissemination strategy: **provider route forwarding rule**

• **Stage 2**: Downhill resolution
  – The forwarding of the `Consume` request down from the CRME that has the content record to the explicit content server that hosts the content
  – `Consume` message dissemination strategy: follows the content repository entry
Content Resolution

Downhill: follows content repository entry

Uphill: provider route forwarding rule

A

A.A

A.A.A

S1

A.B

A.B.A

C2::Consume(X1)

X1->A.A

X1->A.A.A

X1->S1

??
• Resolution modes:
  – Scoped mode
    • specific source(s) only
    • forwarding of request follows BGP routes
  – Wildcard mode
    • any source(s) in the Internet
    • forwarding of request follows business relationships between domains (the provider route forwarding rule)
  – Filtered mode
    • NOT from specific source(s); via EXCLUDE option
    • forwarding of request follows business relationships between domains (the provider route forwarding rule)
• Basic features

- The setup of content delivery paths is coupled with the corresponding content resolution paths
- **Content states** are installed (by CRME) at the CAFEs located at the edge of each domain during the content resolution phase
- **Content Forwarding:**
  - Content is delivered across a set of CAFEs with installed content state by local CRME
  - Interaction with native IP within each domain: either through tunnels (short-term) or following a more native approach like CCN (long-term)

• Advanced features

- Inter-domain routing optimisation
  - Recall that content resolution operations are basically based on the business relationship between neighbouring ISPs
  - Possible shortcut content delivery paths captured from BGP routing information after the content resolution phase
CRME Interaction with CAFEs

**CRME Functions**
- Forwarding content resolution requests across domains
- Configuring content states at local ingress and egress CAFEs
- **NOT** responsible for carrying content flows (physically decoupled from CAFE)
• **Where** – Content states are only maintained at CAFEs that are normally planted at the network edge as ingress/egress nodes

• Core IP routers within the network are **not** content-aware and hence do not recognise the content identifier

• **Content forwarding rules at CAFEs (supporting inter-domain multicast)**
  - Each ingress CAFE receives the content from its upstream egress CAFE in the previous-hop domain and forwards to all the local egress CAFEs which have the same state
  - Each egress CAFE receives the content from its local ingress CAFE and forwards to all the downstream ingress CAFEs in the next-hop domains which have the same state
• Analogous to BGP routing policy – “prefer customer route over peering route, and *prefer peering route over provider route*”

• Basic idea
  - A shortcut peering route (learned from BGP) is preferred over a provider route that was originally identified by the content resolution process

• Approach

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Content flow initially follows the provider route determined in the resolution phase

Shortcut peering route available? Yes

New scoping-based content resolution request sent from the local domain

Path switching from provider route to short-cut peering route

Routing awareness
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CRME in domain 1/8 is aware:
For context ID X:
Ingress CAFE = 1.0.0.2
Egress CAFE = {1.0.0.1}

Content consumer A is currently Receiving the content X from S

- Content consumer A is currently Receiving the content X from S
- stands for content state for X
Content consumer B starts to request the content X with wildcard.

CRME in domain 1/8 update for context ID X:
- Ingress CAFE = 1.0.0.2
- Egress CAFE = {1.0.0.1, 1.0.0.3}
An Example

- CRME in domain 1.1/16 starts to switch to a peering route.
- Once CAFE 1.1.0.1 has received the content X from the peer route it stops sending join requests on the provider route
The coupled approach follows hop-by-hop paradigm for content resolution and consumption.

- Content resolution paths at the domain level is used for content delivery
- Offers graceful support of **inter-domain multicast**
- Offers **bi-directional location-independence**
  - Explicit source and receiver locations are never exposed to each other
  - Strengthening security aspect of the infrastructure
- Offers **locational preference indication** via scoping and filtering functions
COntent Mediator architecture for content-aware nETworks