CSE 534
Future Internet Architectures

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With content from: Srinivasan Seshan, Dongsu Han
Assigned reading

• CCN
  – Lots of authors!
  – Key idea?
  – If CCN is the solution, what's the problem?

• XIA
  – Even more authors!
  – Key idea?
  – If XIA is the solution, what's the problem?
Likes/Dislikes

• Like
  – Rethinking old assumptions
  – Attempt to redo host/network interfaces
    • “Abstractions”
  – Clean ideas

• Dislike
  – Writing/Techniques/Eval
  – Incentives? Economics?
  – If content is really the motivator, this seems heavy
  – Technical problems solved seem tangential/secondary
Outline

• Why something new?

• CCN

• XIA
IP: Narrow Waist of the Internet

Applications

IP

Innovation both above and below IP

Technology

But what about IP?
Communication patterns have changed

• In the beginning...
  – First applications strictly focused on host-to-host interprocess communication:
    • Remote login, file transfer, ...
  – Internet was built around this host-to-host model.
  – Architecture is well-suited for communication between pairs of stationary hosts.

• ... while today
  – Vast majority of Internet usage is data retrieval and service access.
  – Users care about the content and are oblivious to location. They are often oblivious as to delivery time:
    • Fetching headlines from CNN, videos from YouTube, TV from Tivo
    • Accessing a bank account at “www.bank.com”.
Innovation is Hard

- Imagine: You have a novel data transfer technique
- How do you deploy?
  - Update HTTP. Talk to IETF. Modify Apache, IIS, Firefox, Netscape, Opera, IE, Lynx, Wget, …
  - Update SMTP. Talk to IETF. Modify Sendmail, Postfix, Outlook…
  - Give up in frustration
New Challenges

• Very large E2E delay
  – Propagation delay = seconds to minutes
  – Disconnected situations can make delay worse
• Intermittent and scheduled links
  – Disconnection may not be due to failure (e.g. LEO satellite)
  – Retransmission may be expensive
• Many specialized networks won’t/can’t run IP
Future *-Centric Networking

• Service, content, mobility, and cloud did not receive much attention before as now
• Yet more networking styles may be useful in the future
  – E.g., DTN, wide-area multicast, …?
What can you do differently?

• Evolve through indirection?

• Evolve through programmability?

• Evolve through virtualization?

• Evolve through better abstractions?
Outline

• Why something new?

• CCN

• XIA
Google…

Biggest content source

Third largest ISP

1995 - 2007: Textbook Internet

2009: Rise of the Hyper Giants

What does the network look like…
CCN Model

- Packets say ‘what’ not ‘who’ (no src or dst)
- communication is to local peer(s)
- upstream performance is measurable
- memory makes loops impossible
Context Awareness?

• Like IP, CCN imposes no semantics on names.

• ‘Meaning’ comes from application, institution and global conventions:

  /parc.com/people/van/presentations/CCN
  /parc.com/people/van/calendar/freeTimeForMeeting
  /thisRoom/projector
  /thisMeeting/documents
  /nearBy/available/parking
  /thisHouse/demandReduction/2KW
CCN Names/Security

/nytimes.com/web/frontPage/v20100415/s0/0x3fdc96a4...

signature
0x1b048347

nytimes.com/web/george/desktop public key

Signed by nytimes.com/web/george
Signed by nytimes.com/web
Signed by nytimes.com

• Per-packet signatures using public key
  – Packet also contain link to public key
Names Route Interests

- FIB lookups are longest match (like IP prefix lookups) which helps guarantee log(n) state scaling for globally accessible data.
- Although CCN names are longer than IP identifiers, their explicit structure allows lookups as efficient as IP’s.
- Since nothing can loop, state can be approximate (e.g., bloom filters).
CCN node model
CCN node model

get /parc.com/videos/WidgetA.mpg/v3/s2

get /parc.com/videos/WidgetA.mpg/v3/s2
Flow/Congestion Control

• One Interest pkt $\rightarrow$ one data packet

• All xfers are done hop-by-hop – so no need for congestion control

• Sequence numbers are part of the name space
What about connections/VoIP?

- Key challenge - rendezvous
- Need to support requesting ability to request content that has not yet been published
- E.g., route request to potential publishers, and have them create the desired content in response
CCN Summary

• Content, not host is first-class citizen

• Routers can have content stores

• Routing/forwarding is name based

• Names are prefix-encoded
  – Support for future contents etc

• Intrinsic support for: multicast, security, mobility
Outline

• Why something new?

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Legacy Router May Prevent Innovation

Problem: Using a new communication type may require every legacy router in the network to be upgraded.

Can we allow using a new communication type even when the network is yet to natively support it?

“I got a computer with Awesome-Networking announced in NSDI 2022! Can I use it right now?”

“Ouch, we just replaced all of our routers built in 2012. Can you wait for another 10 years for new routers?”
XIA’s Goals and Design Pillars

“Principal types”

Support multiple communication types (heterogeneity)

Support future communication types (evolution)

“Fallbacks”

Allow using new communication types at any point (incremental deployment)
Principal Types

Define your own communication model
# Principals

<table>
<thead>
<tr>
<th>Current Internet</th>
<th>XIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP address</td>
<td></td>
</tr>
<tr>
<td>128.2.10.162</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Principal type</th>
<th>Type-specific identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host</td>
<td>0xF63C7A4...</td>
</tr>
<tr>
<td>Service</td>
<td>0x8A37037...</td>
</tr>
<tr>
<td>Content</td>
<td>0x47BF217...</td>
</tr>
<tr>
<td>Future</td>
<td>...</td>
</tr>
</tbody>
</table>

- Hash of host’s public key
- Hash of service’s public key
- Hash of content
Principal Type-Specific Semantics

Contact a host

Use a service

Retrieve content
Principal Type-Specific Processing

- Type-specific processing examples
  - Service: load balancing or service migration
  - Content: content caching
Routers with Different Capabilities

- Routers are **not** required to support every principal type
  - The only requirement: Host-based communication

![Diagram showing Host-only router, Service-enabled router, and Content-enabled router]
Using Principal Types that are Not Understood by Legacy Routers?

Content-enabled router

Legacy router
without content support

Want to communicate using content principals

Content-enabled router
Fallbacks

Tomorrow’s communication types... today!
Fallbacks: Alternative Ways for Routers to Fulfill Intent of Packet

Intent: Retrieve Content

Fallback: Contact Host, who understands Content request

What the network does:

• With content-enabled routers, use Content for routing
• Otherwise, use Host for routing (always succeeds)
DAG-Based Address

Your address is more than a number
DAG (Direct Acyclic Graph)-Based Addressing Enables Fallbacks

- Packet sender
- Routing choice
- Intent
- Host
- Another routing choice (with lower priority)
- This host knows how to handle content request
- Fallback

Content

This host knows how to handle content request

Packet sender

Routing choice

Intent

Host

Another routing choice (with lower priority)

Fallback
DAG Addresses in Packet Header

Common fields
(Size, Hop limit, ...)

Destination address

Source address

(Extension headers)

Payload

Including in-packet state for forwarding

For forward path

For return path

DAG encoding in paper
Scoping Using DAG

More specific intent & Better scalability
Service Binding with DAG

Initial contact to a service

When a particular host should serve subsequent service requests

“Late binding”
DAG Allows Nested Fallbacks

Domain ➔ Host ➔ Service ➔ Content

Strong support for evolvable internetworking
Can We Forward DAGs Rapidly?

Expressive ≠ Expensive
XIA Software Router’s High Forwarding Throughput

Click-based implementation on commodity hardware
351 K table entries based on a Route Views snapshot

≤26% slowdown for small packets with 3 fallbacks
XIA: eXpressive Internet Architecture

• Support for evolvable internetworking
  – Heterogeneous communication types
  – Future communication types
  – Incremental deployment of new communication types

• Principal types & fallbacks

• DAG-based addressing
Takeaways

• Internet has changed
  – New apps
  – New requirements
  – New challenges

• What should the future network be?
  – Flexible? Evolvable? Content-centric?

• CCN, XIA are some samples
Reminders

• Take home this weekend

• Class project reports due May 15
  — Extensions?
XIA: Enabling Evolution by eXpression

- Prototype: github.com/XIA-Project/xia-core
  - Router, socket, content cache, etc.
  - Supports LAN, XIA-over-IP, GENI
**Caller (Alice)**

**Callee (Bob)**

<registers a desire to see interests asking for content beginning with `/domain/sip/bob/invite`>

**Interest:**
```
/domain/sip/bob/invite/E_{pkB}(sk)/E_{sk}(SIP INVITE message)
```

**Data:**
- **Name:** `/domain/sip/bob/invite/E_{pkB}(sk)/E_{sk}(SIP INVITE message)`
- **Signature Info:** `<metadata>, <signature>`
- **Content:** $E_{sk}(SIP response message)$

**Interest:**
```
/domain/bob/call-id/rtp/seq-no
```

**Data:**
- **Name:** `/domain/bob/call-id/rtp/seq-no`
- **Signature Info:** `<metadata>, <signature>`
- **Content:** SRTP packet (encrypted audio)

**Interest:**
```
/domain/alice/call-id/rtp/seq-no
```

**Data:**
- **Name:** `/domain/alice/call-id/rtp/seq-no`
- **Signature Info:** `<metadata>, <signature>`
- **Content:** SRTP packet (encrypted audio)