Trust in Information-Centric Networking

From Theory to Practice

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Agenda

- ICN and CCN overview
- Content-Based Security and Trust
- Core trust logics for verification/signing
- CCNx Trust Engine Design
- Conclusion

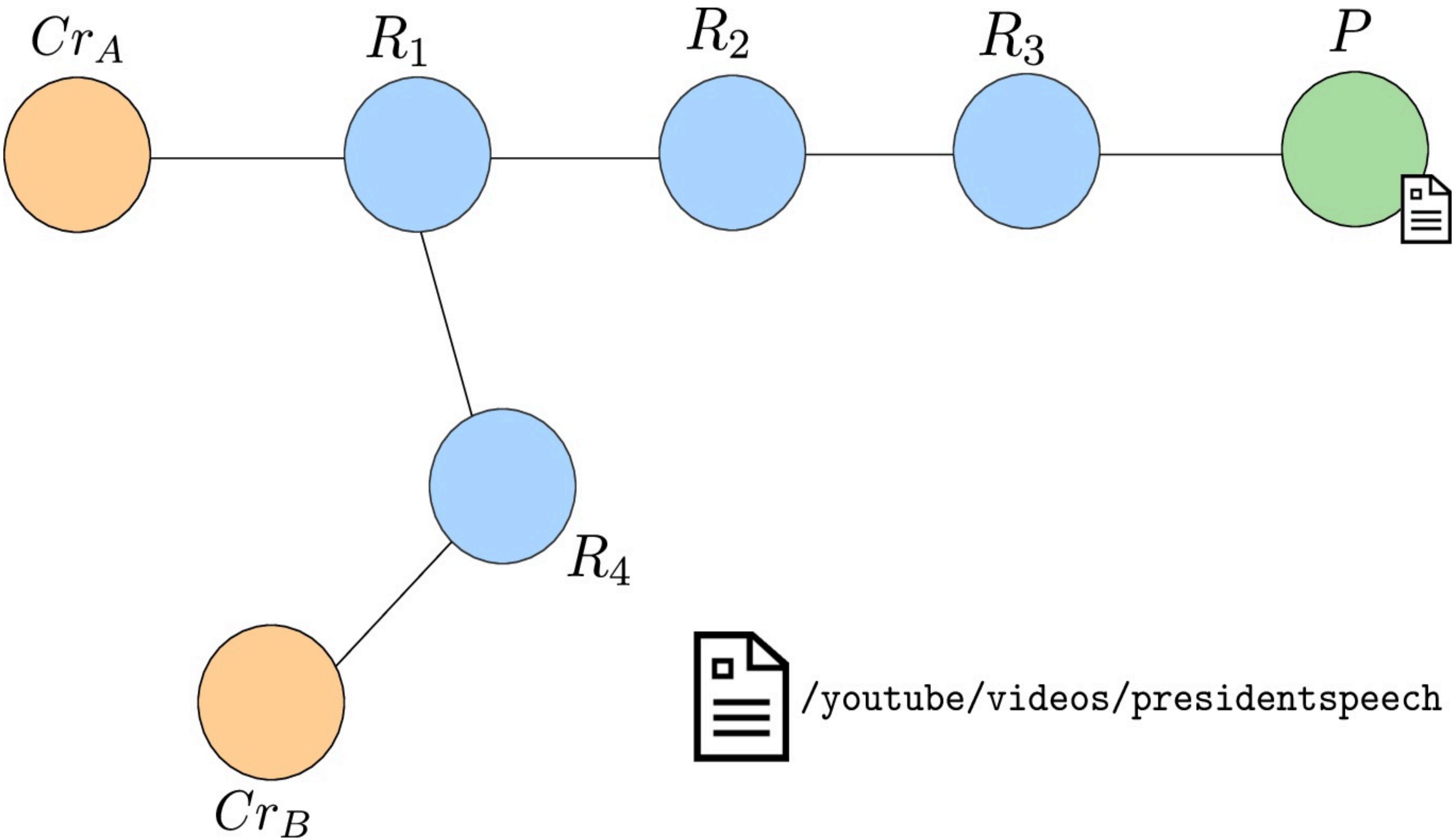
Information Centric Networks

- Aims to evolve away from a host-centric paradigm to a network architecture in which the focal point is “**named information**”.
- **Mobility** and **multi access** are the norm and **anycast, multicast, broadcast** are usually natively supported.
- **Data is independent from location, application, storage, and means of transportation**, enabling in-network caching and replication.

CCN Overview

- CCN (and its sister architecture NDN) is one well known example of ICN
  - Data is obtained via an explicit request for the name with an **interest**
  - **Consumers** issue interests that are routed towards the data **producer** (using the name)
  - A **content object** carries the data back to the consumer

Example



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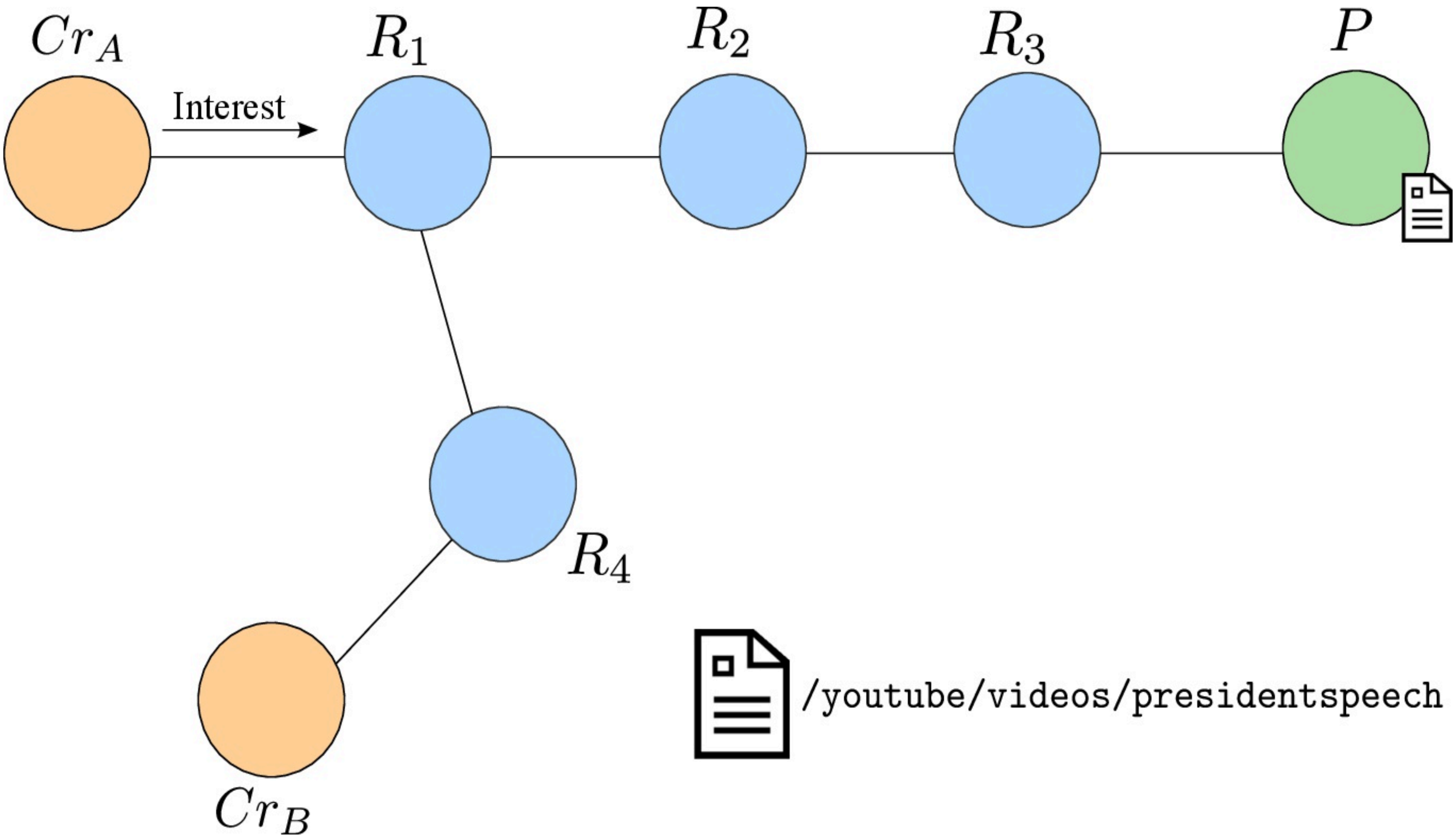

Cr_A
Interest
R_1
R_2
R_3
P
R_4
Cr_B
/youtube/videos/presidentspeech

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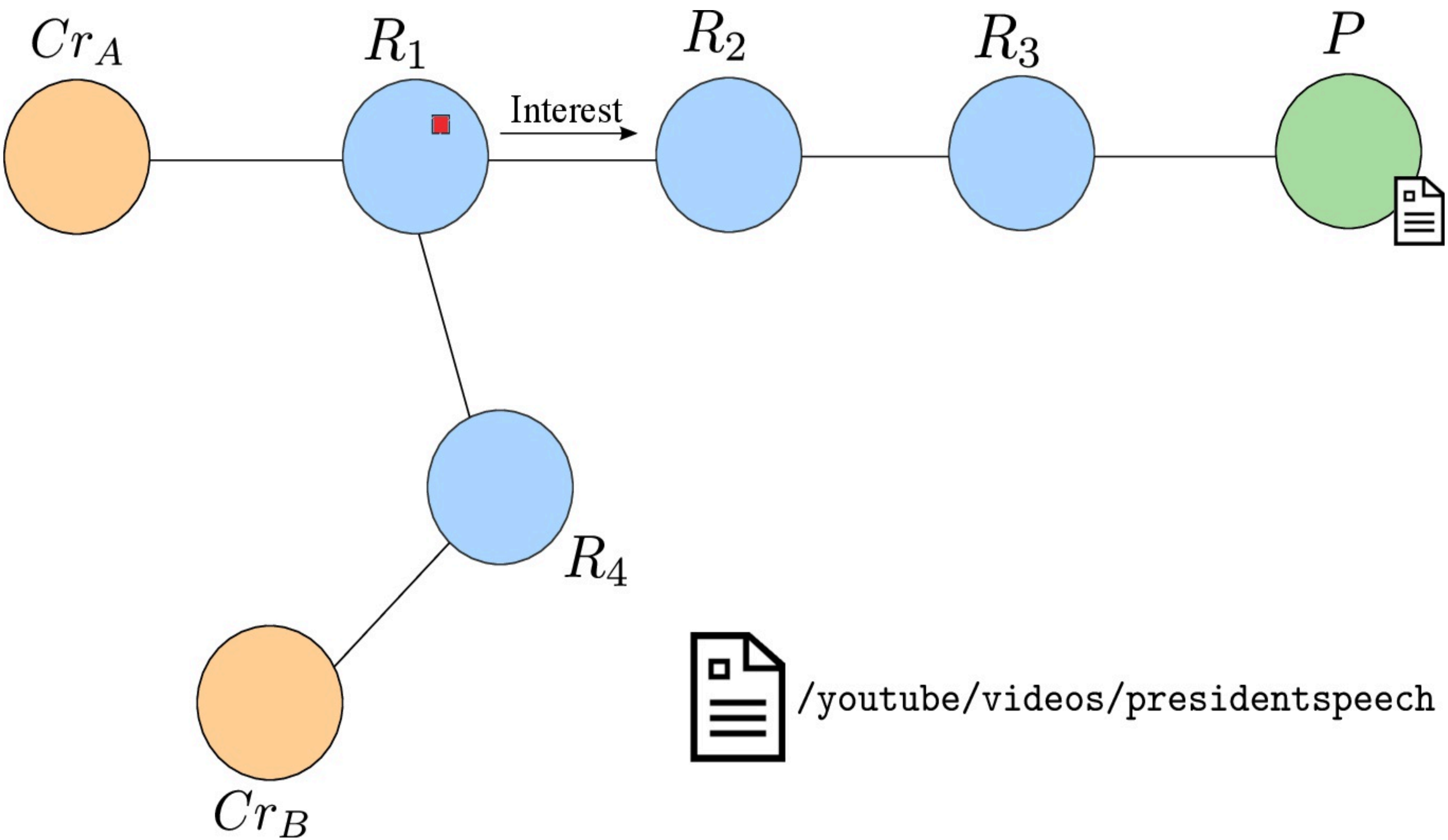

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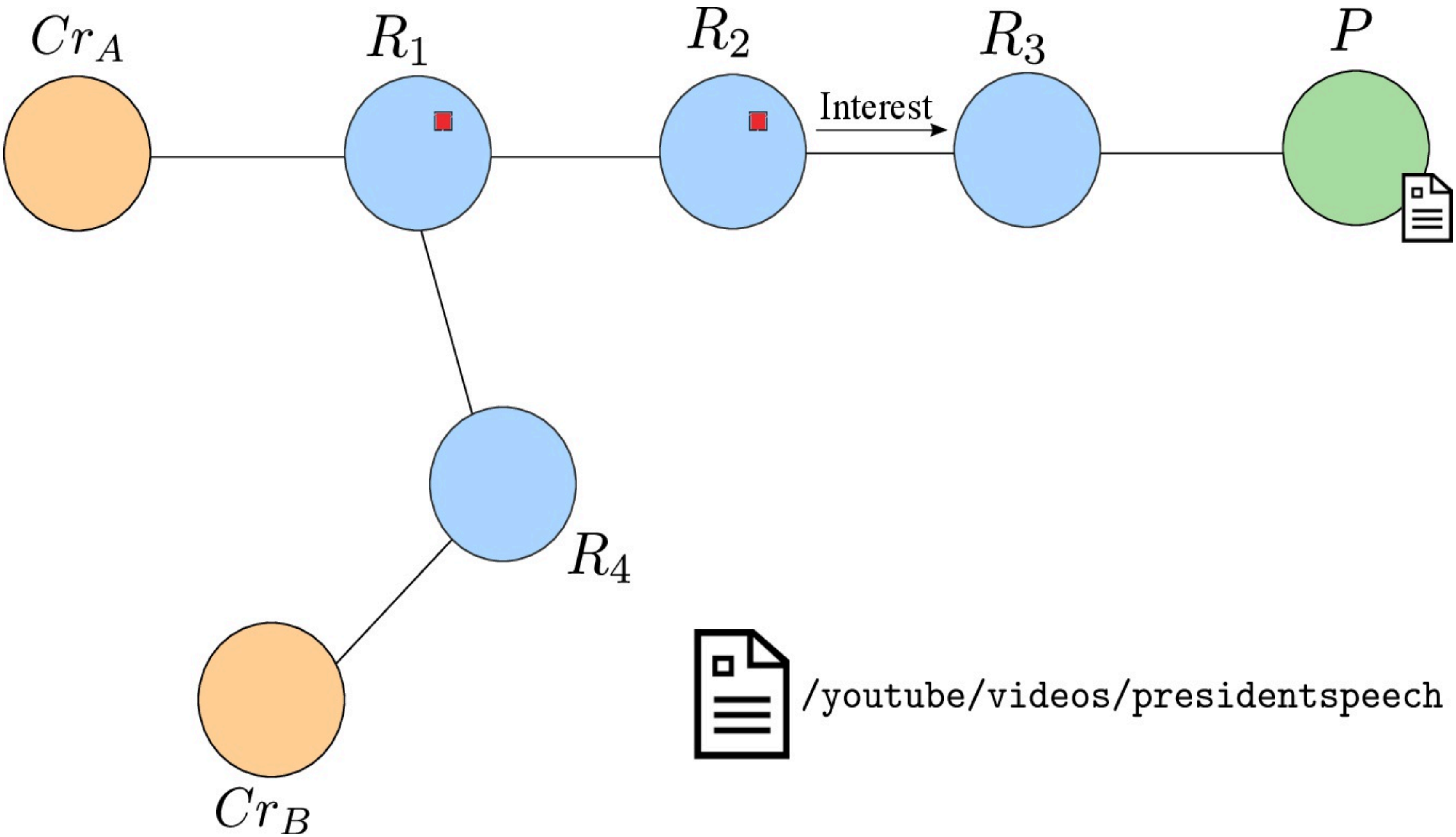

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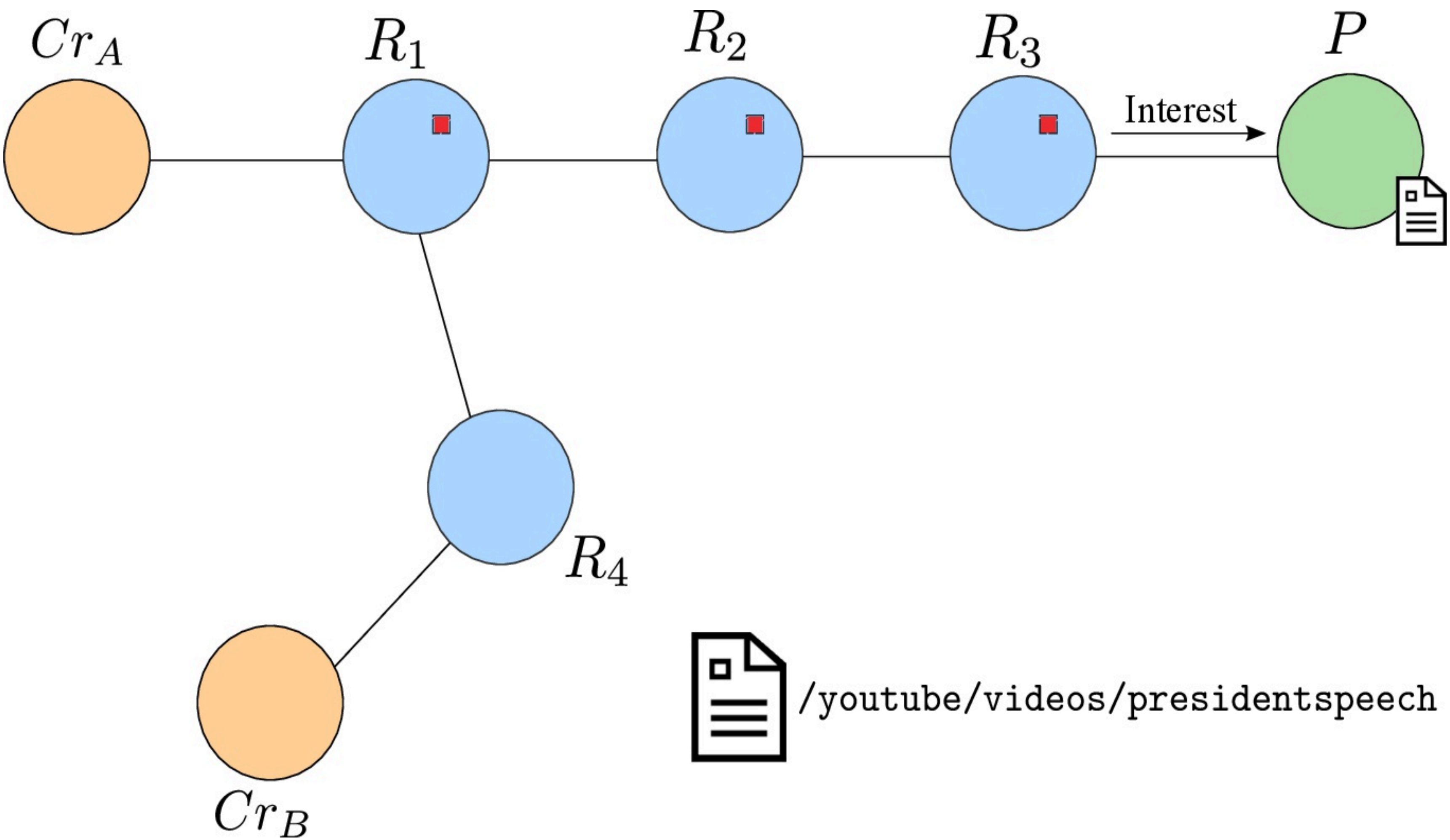

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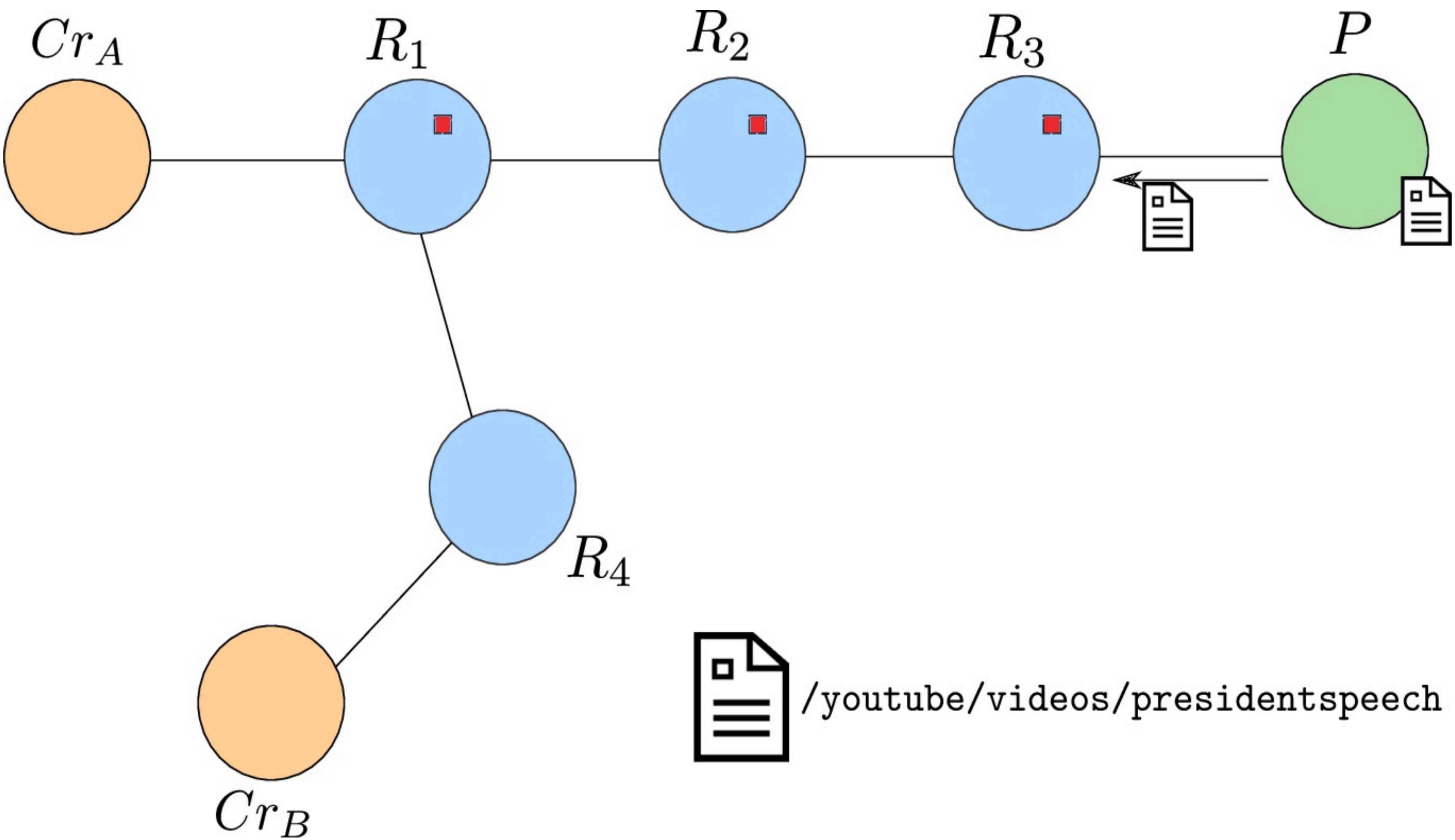

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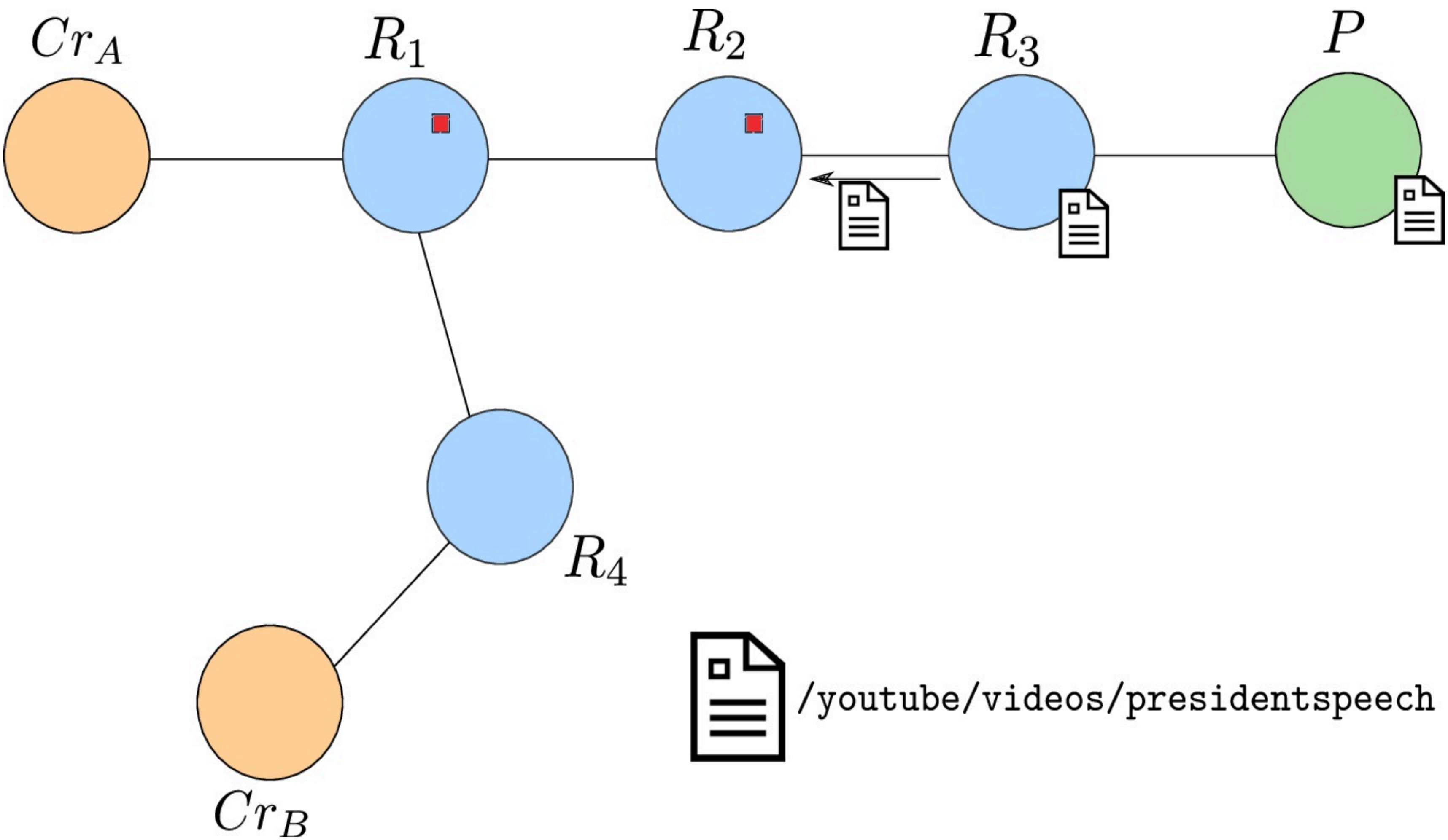

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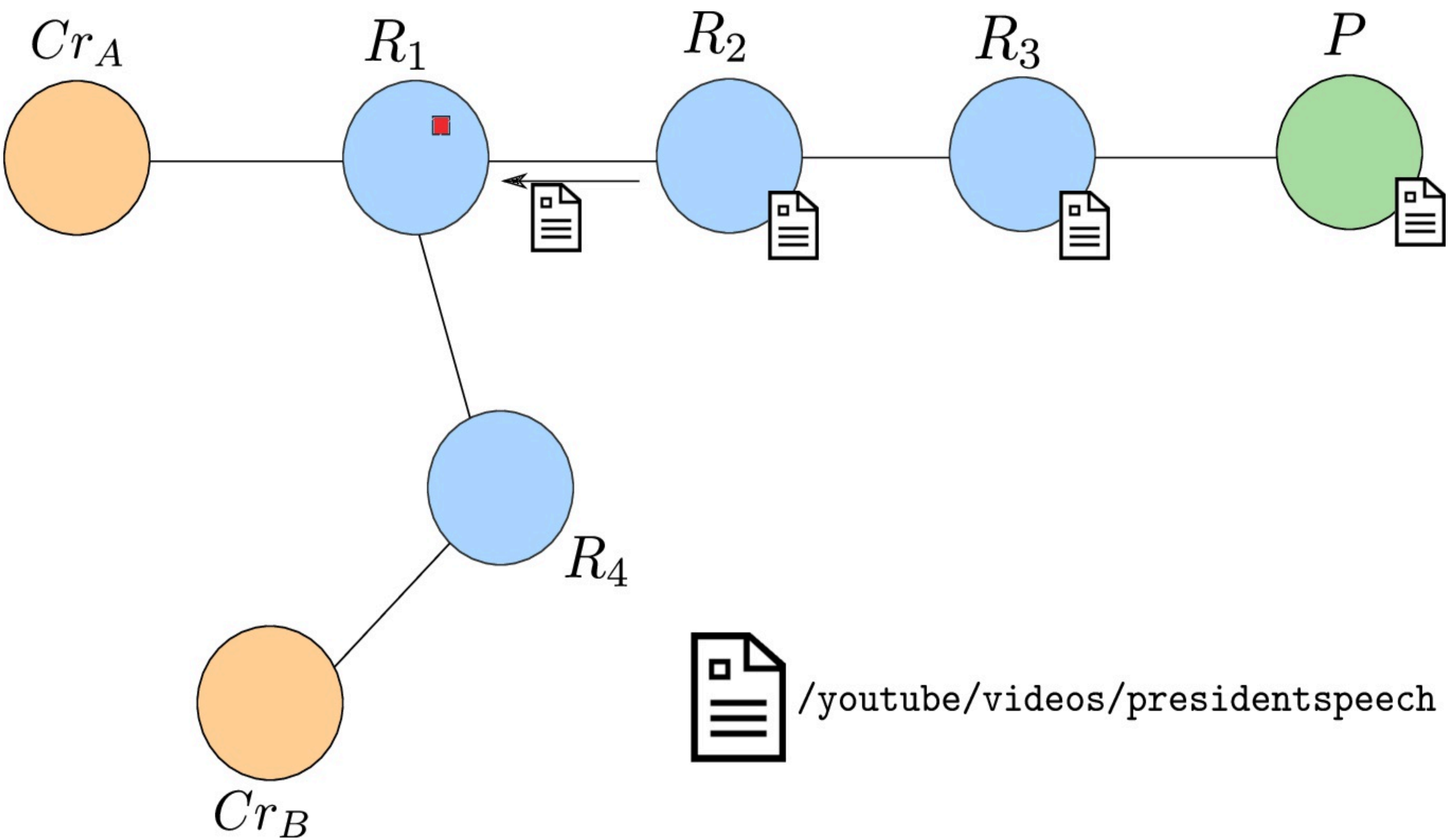

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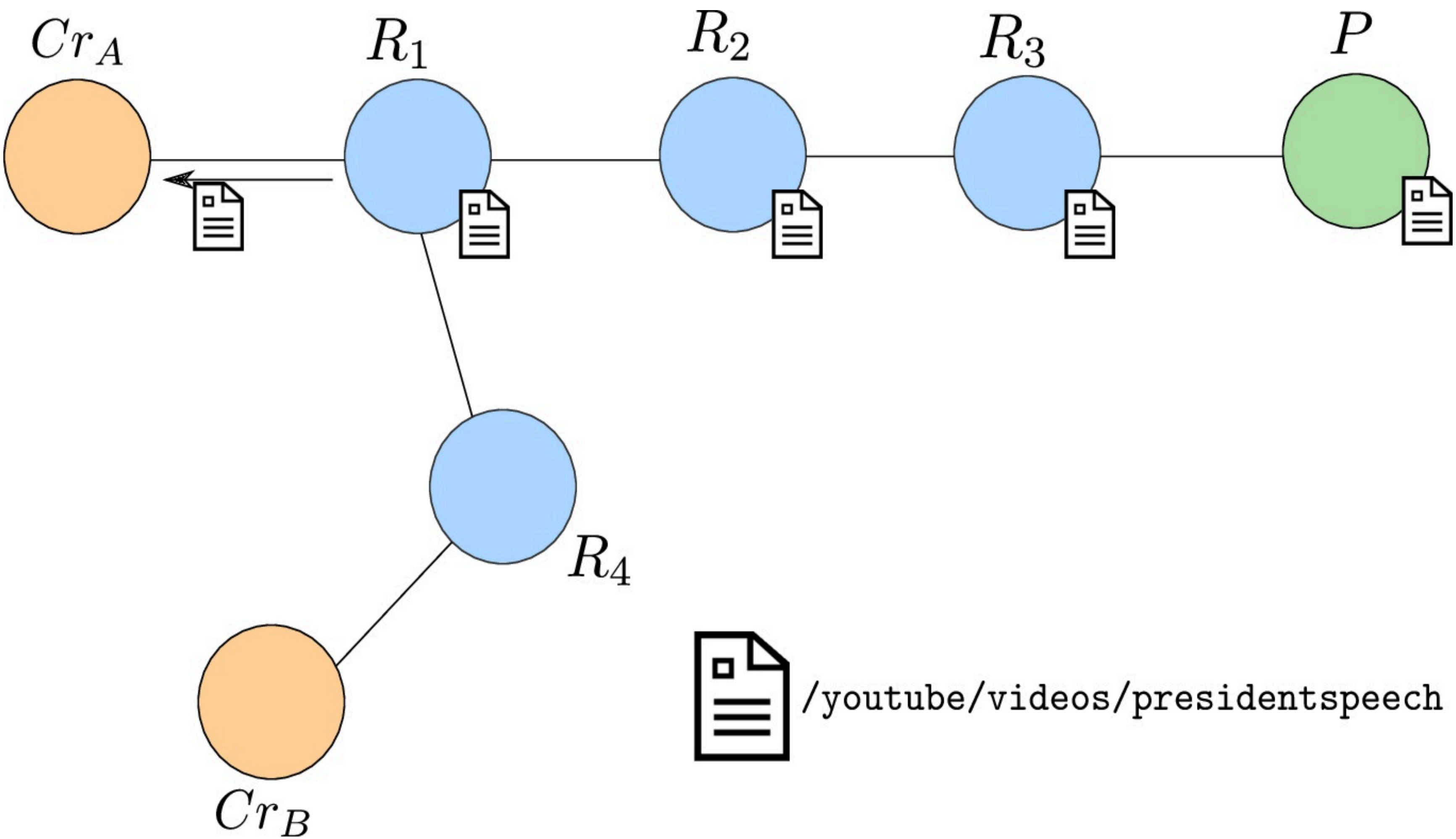

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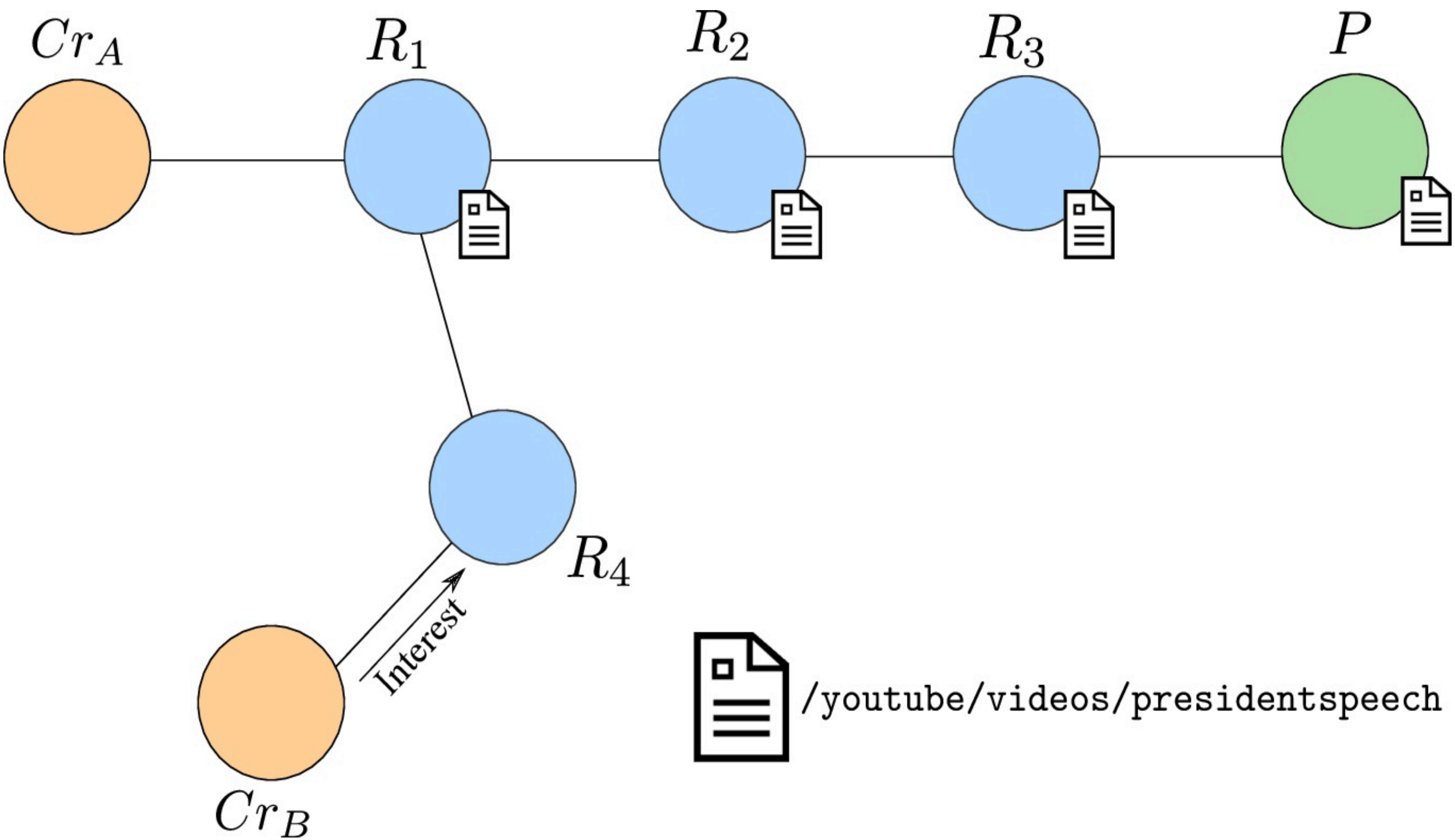
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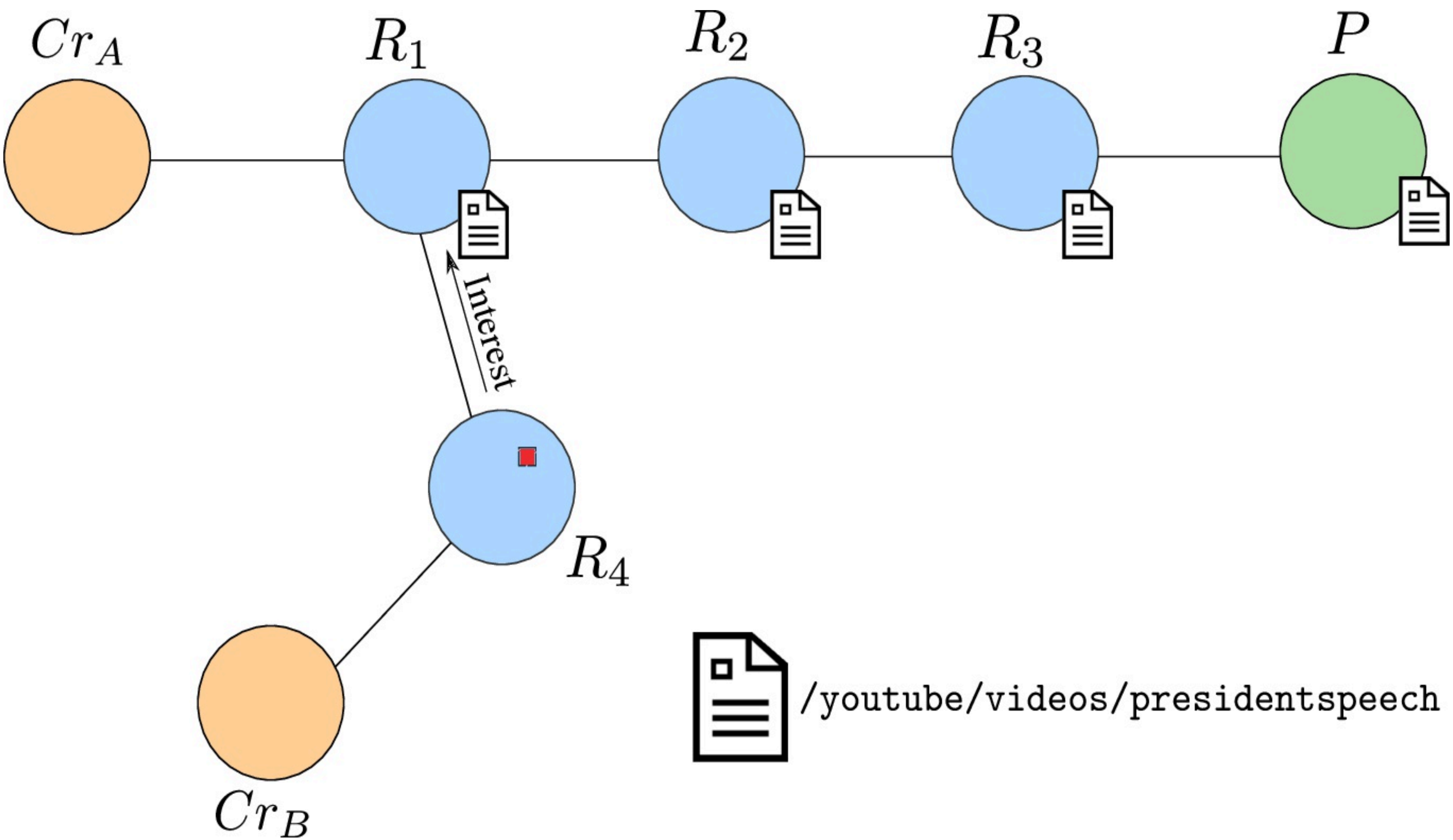

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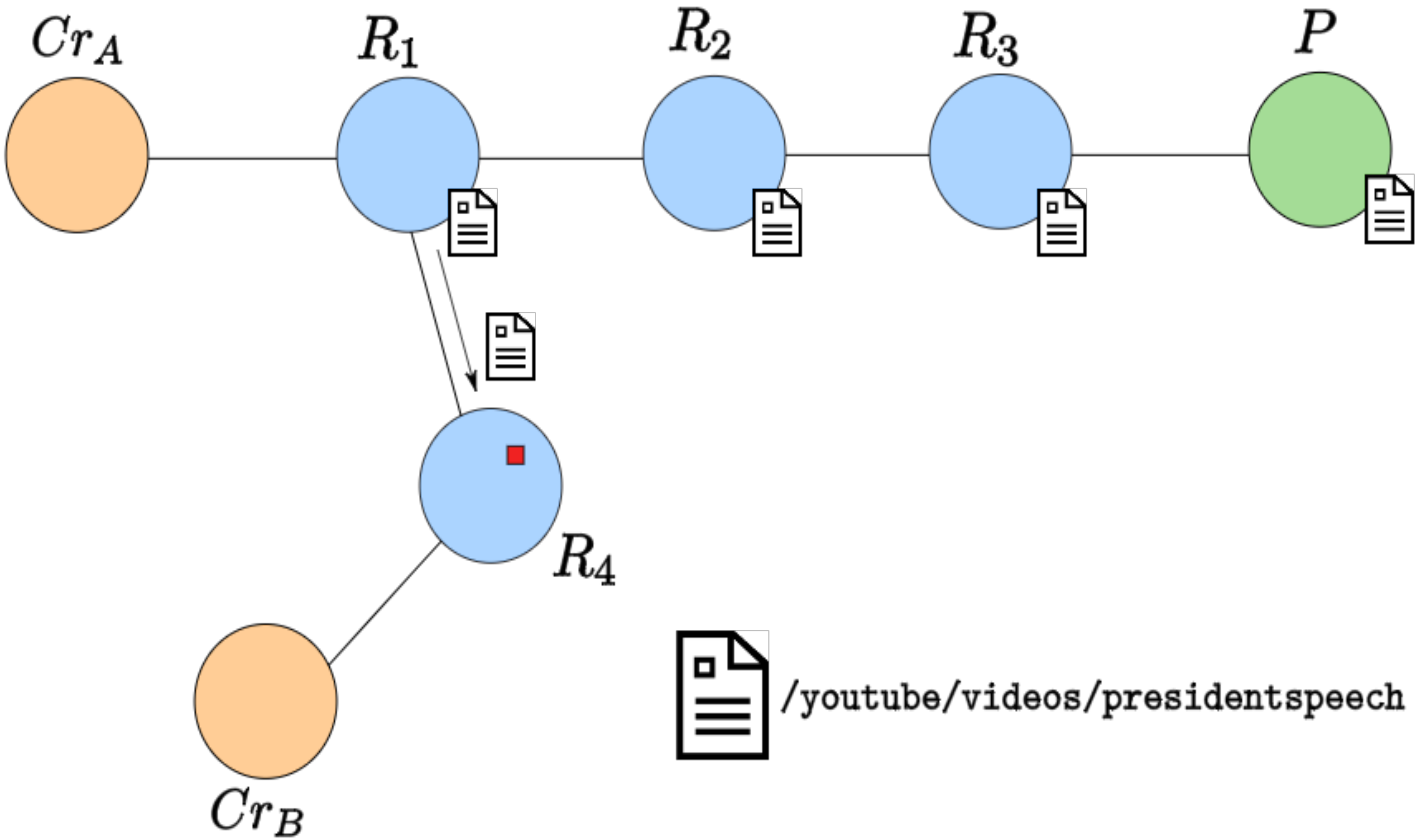

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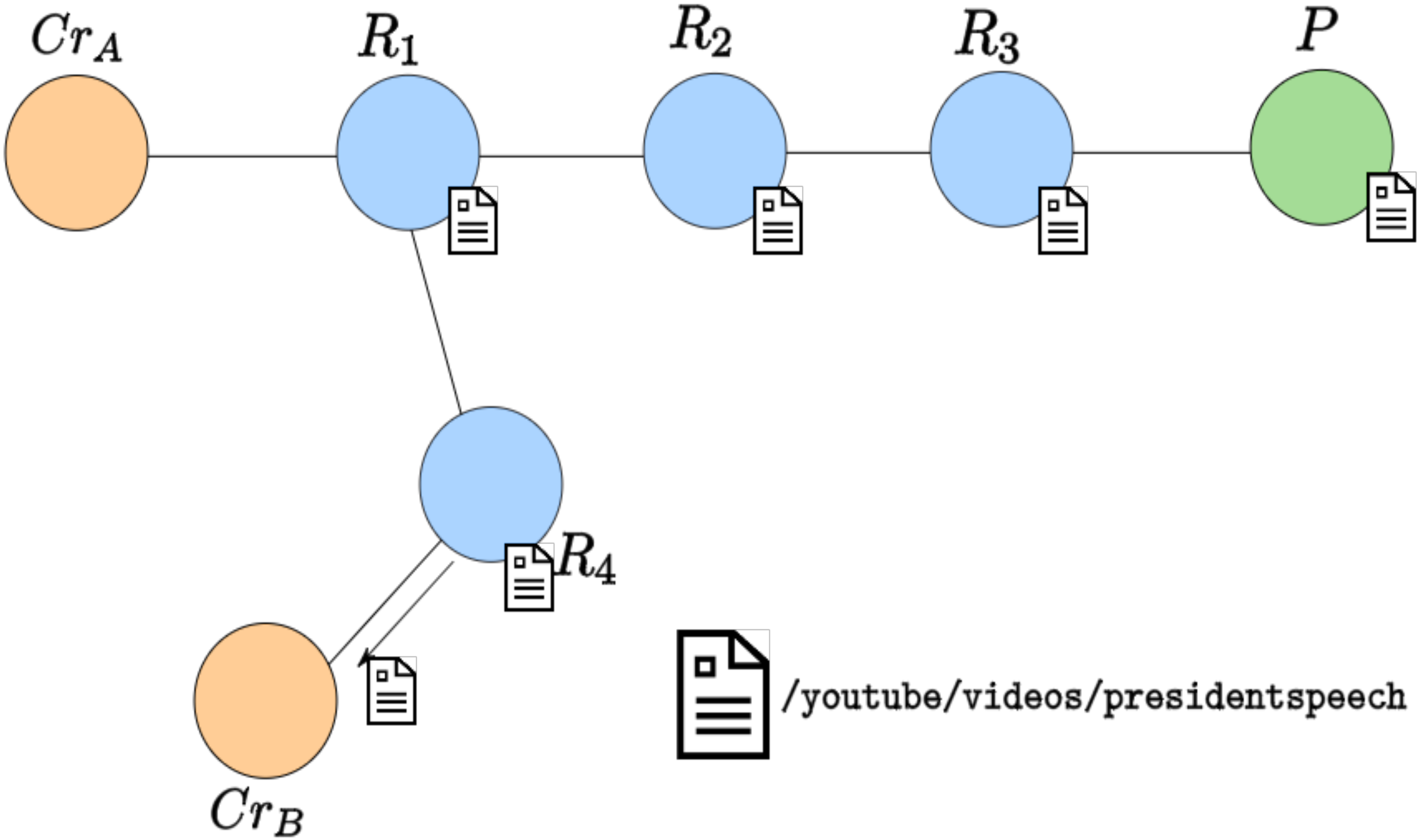
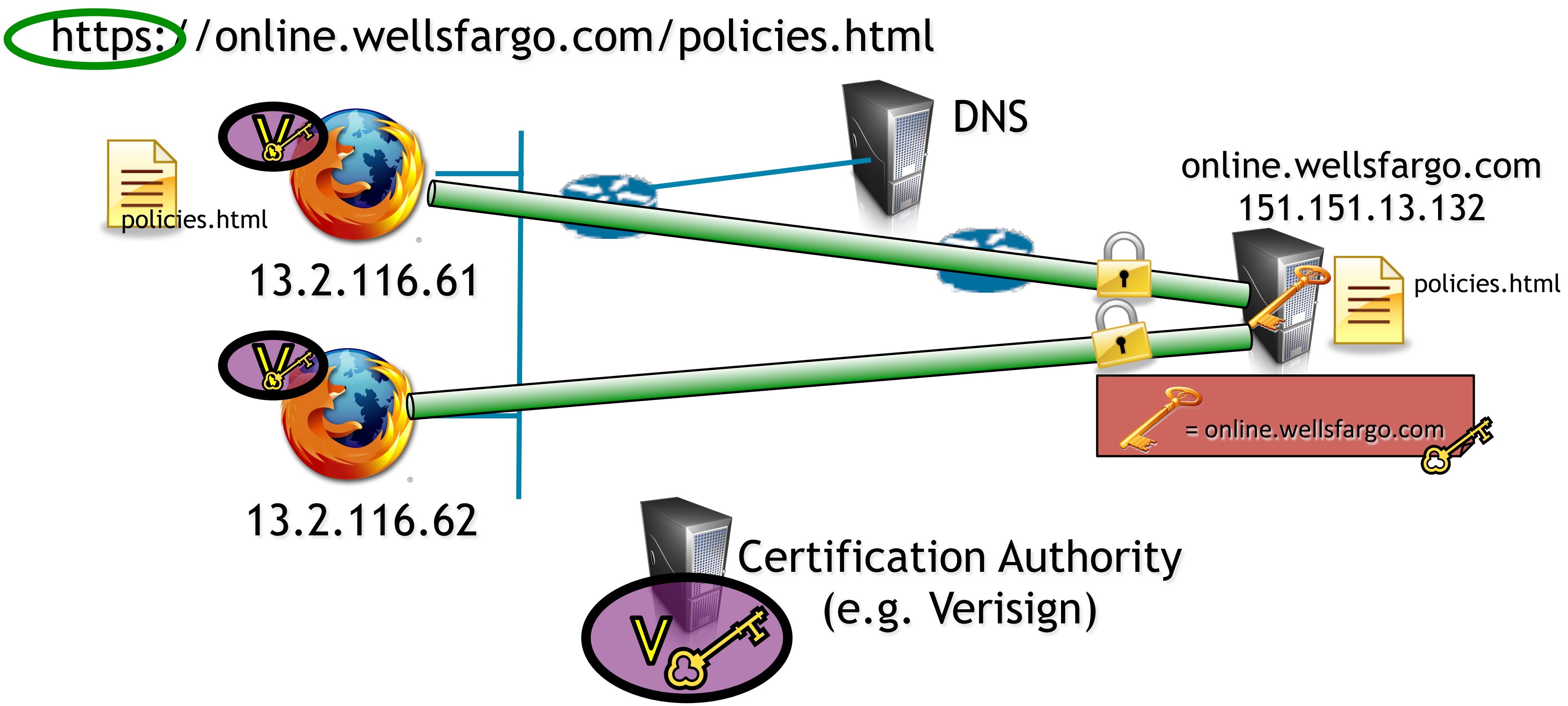


Content-Based Security

Connection-Based Security

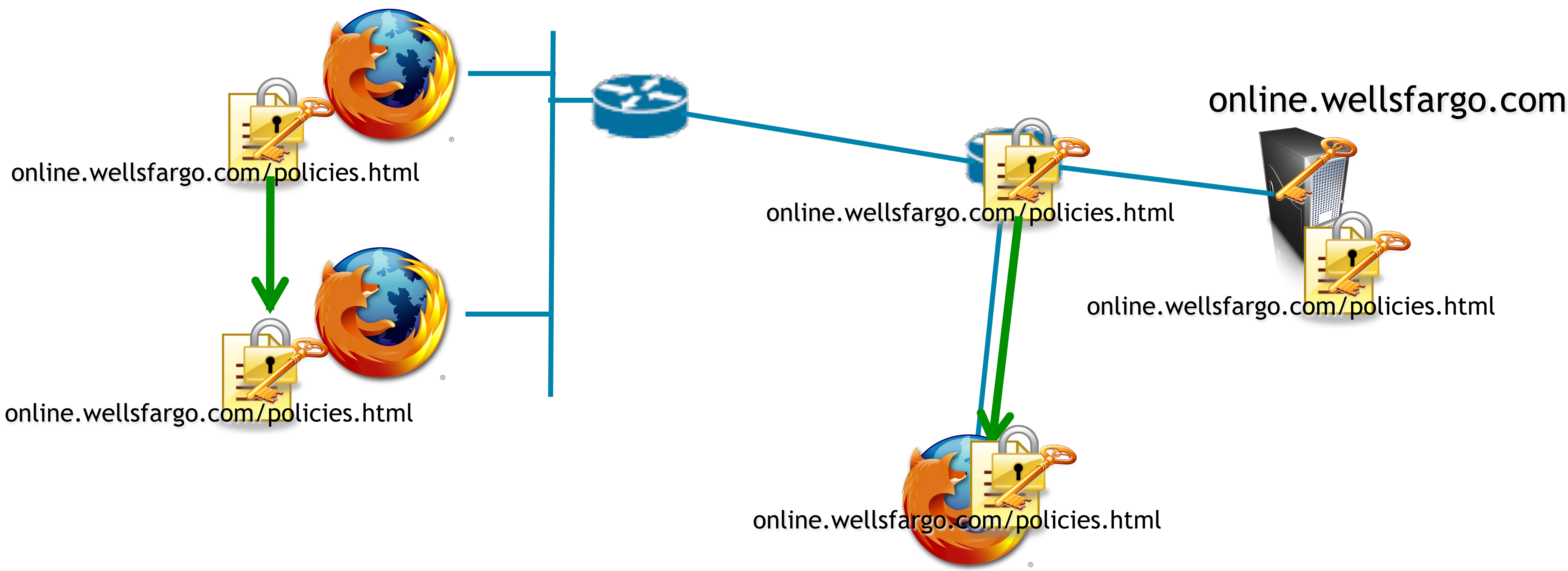
Today's internet secures *connections,* not *content:*



Content-Based Security

Secure the *content*, wherever it travels…
…get it from anyone who has a copy.

online.wellsfargo.com/policies.html



Securing Content in CCN

Content Packet = ⟨ *name*, *data*, *signature* ⟩

In theory, any consumer can verify:

- Integrity: is data intact and complete?
- Origin: who asserts this data is an answer?
- Correctness: is this an answer to my question?

Trust in Application-Layer

- How does a consumer application determine which content is trusted?
  - A valid digital signatures doesn't mean content is authentic or trustworthy
  - Trust decisions can only be made within a particular and potentially complex trust context (e.g., given set of trust anchors, rules and exceptions).

Trust in Network-Layer

- How network-layer machinery can enforce trust context of applications?
  - How do routers determine what content they should/can use to respond to requests
  - How the network stack can request/deliver content that the application would trust

Sample Trust Models

- Pre-shared keys
  - Massage Authentication Codes
- PKI
  - Traditional
  - Constrained
    - e.g., Yu et. al., Schematizing trust in NDN
- Web-of-Trust
  - PGP

Theory to Practice

- **Architectural design** that enables efficient representation and enforcement of trust preferences at the network-layer
  - CCNx requests can have either of content hash or publisher Key ID restrictions

- **A design/implementation of a machinery** that can translate any application-layer trust semantics to network-layer mechanics and enforce them during content publishing/consumption.

In this paper, we show the design logic and an instance implementation of such a machinery in CCNx.

Core Validation Logic

```
isValidPkt(Packet, TrustContextIn, TrustContextOut) :-
  Packet = pkt(DataName, _, KeyInfo, PktHash, PktSignature),
  getTrustedKey(DataName,KeyInfo,TrustContextIn,TrustContextOut),
  KeyInfo = key(_, _, KeyBits),
  isValidSignature(PktHash, PktSignature, KeyBits),
```

- System tries to satisfy the isValidPkt() predicate by getting a trusted key and validating the packet's signature.
- A *packet* has a name, the information regarding which key was used to sign, the hash value (and the signature value.
- *KeyInfo* usually has key's name, ID, and always the key value

- Underscore is used to leave some fields optional

Core Validation Logic

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  KeyInfo = key(_, _, KeyBits),
  isValidSignature(PktHash, PktSignature, KeyBits),
```

In our trust context … or not

```
getTrustedKey(_, KeyInfo, TrustContext, TrustContext) :-
  TrustContext = trustCtx(_, TrustedKeyList, _),
  member(KeyInfo, TrustedKeyList).

getTrustedKey(DataName,KeyInfo,TrustContextIn,TrustContextOut) :-
  fetchTrustedKey(DataName,KeyInfo,TrustContextIn,TrustContextOut).
```

All differences among the trust models are now isolated to the getTrustedKey() predicate

Model-Specific Variations: MAC

```
fetchTrustedKey(_, _, Context, Context) :-
  Context = trustCtx('preshared', _, _), fail.
```

- In the simplest trust model, symmetric session keys are pre-shared
- Consequently, the fetchTrustedKey() is a failing action if the key is not already known

Model-Specific Variations: Hierarchical/Schematized

```
fetchTrustedKey(DataName,KeyHint,TrustContextIn,TrustContextOut) :-
  KeyHint = key(KeyLocator, _, KeyBits),
  TrustContextIn = trustCtx(Model, _, Aux),
  ( Model = 'hierarchical'
  ;
    Model =  'schematized', % Aux has the list of schemas
    member(schema(KeyLocator, DataName), Aux)
  ),
  ccnFetchCert(KeyLocator, CertPkt),
  CertPkt = pkt(KeyLocator, KeyBits, _, _, _),
  isValidPkt(CertPkt, TrustContextIn, TrustContextTmp),
  TrustContextTmp = trustCtx(Model, KeyList, Aux),
  TrustContextOut = trustCtx(Model, [KeyHint | KeyList], Aux).
```

- **Basic hierarchical model**: fetch certificate chain until a trusted certificate is found…
- **Schematized model**: make sure additional constraints on data and key names and explicit authorizations are satisfied.

Signing Logic

- Relatively straightforward as applications usually know their identity and key
- Example logic below consists of find a suitable schema, picking a viable certification path, and signing using the corresponding key

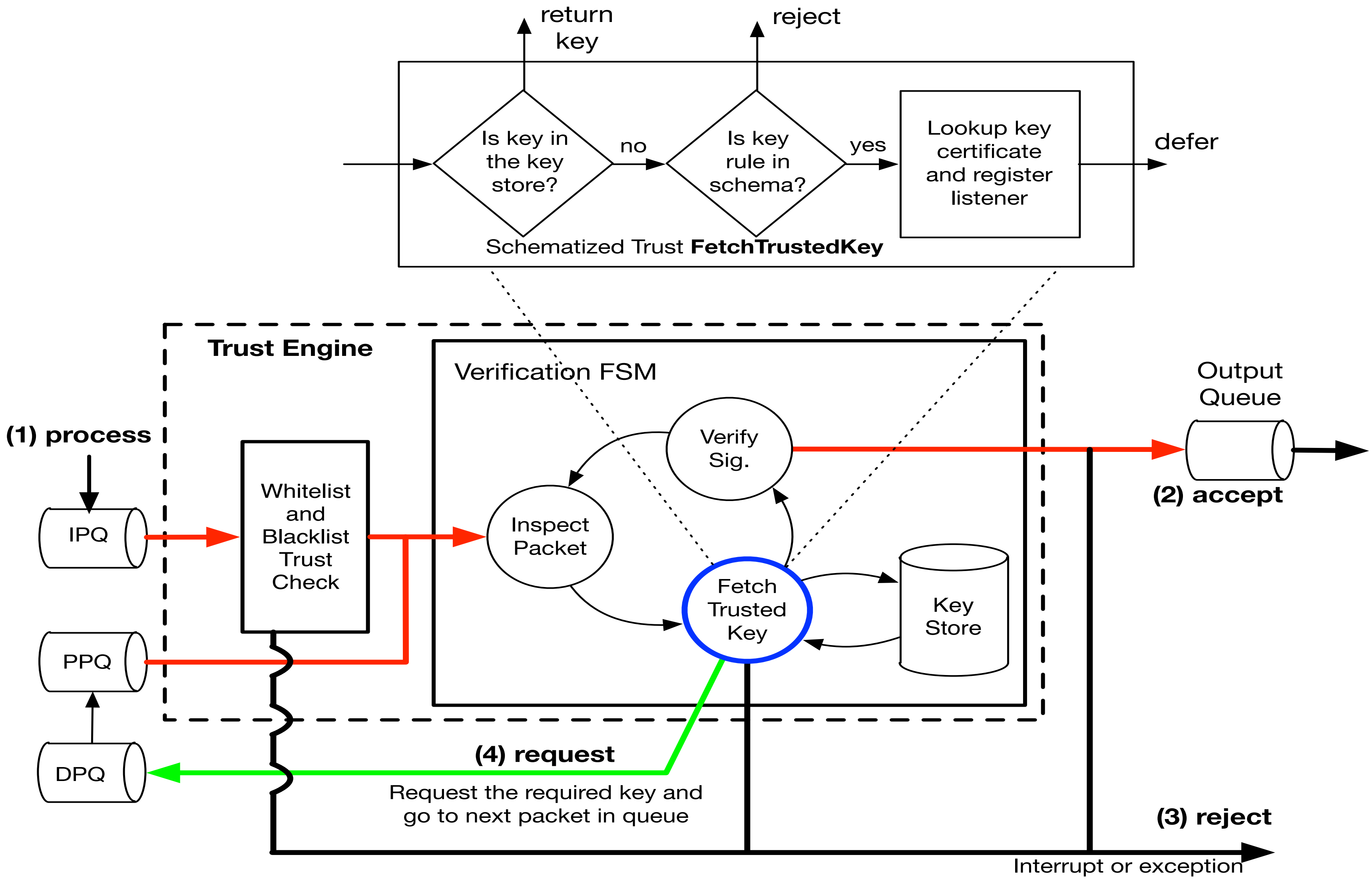
```
getSigningName(NameToBeSigned, TrustContext, [SignerName|Tail]) :-
  TrustContext = trustCtx('schematized', KeyList, Schema),
  member(schema(SignerName, NameToBeSigned), Schema),
  (member(key(SignerName, _, _), KeyList), Tail= []
  ;
   getSigningName(SignerName, TrustContext, Tail)
  ).
```

Theory to Practice: The CCNx Trust Engine Implementation

The trust engine is composed of three functions:

- **InspectPacket**: pull out packet info
- **FetchTrustedKey**: obtain the trusted verification key (and update the trust context).
- **VerifySignature**: verify the signature using the trusted key

CCN Trust Engine Overview



Conclusion

- In ICNs, network needs to deliver content that consumer applications would trust –otherwise it is non-functional!
- This paper demonstrates how to design and implement a machinery that
  - translates trust context/model of applications to network-layer mechanics that can enforce them
  - can handle variety of potentially complex trust models with simple unified logics for easy understanding/ implementation
  - provides easy checks for potential pitfalls such as verification loops and weak certification links
  - is instantiated by a full working implementation on CCNx codebase.

Thanks!

Any question?

You can contact christopher.wood@parc.com for all prolog predicates, TR version of the paper and the CCNx implementation