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CCNX INTEREST AGGREGATION

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ICNRG Interim Meeting, Sept 30, 2016 (Kyoto, Japan)

PRINCIPLES

- Minimize coupling between consumer and forwarders
- No timers on forwarders
- Provable properties

DIFFERENCE FROM ICNRG -03 DRAFT

- Spelled out algorithms in more detail
- Adopted Interest HopLimit decrement idea [1]

[1] J.J. Garcia-Luna-Aceves and M. Mirzazad-Barijough. Enabling Correct Interest Forwarding and Retrans- missions in a Content Centric Network. In *Proc. ACM ANCS'15*, pages 135–146, Oakland, California, 2015.

PROPERTIES (1-3)

1. **Aggregation**: If there are no losses and no retransmissions, then for each link in the forwarding path exactly one Interest and at most one ContentObject traverse the link.
2. **Retransmissions**: If there are retransmissions by one or more consumers and those retransmissions do not pass a ContentObject response in flight, then at most one ContentObject traverses the reverse path.
3. **Interest In Flight**: If a retransmission passes a ContentObject in flight on a given link, then that Interest will propagate only as far as the first cached copy of the response.

PROPERTIES (4-6)

4. **ContentObject In Flight**: If a retransmission passes a ContentObject in flight on a given link, then there will be a duplicate ContentObject sent on that link, but it will not propagate further than that link.
5. **Cycle Termination**: An Interest that travels in a cycle will not repeat the same cycle.

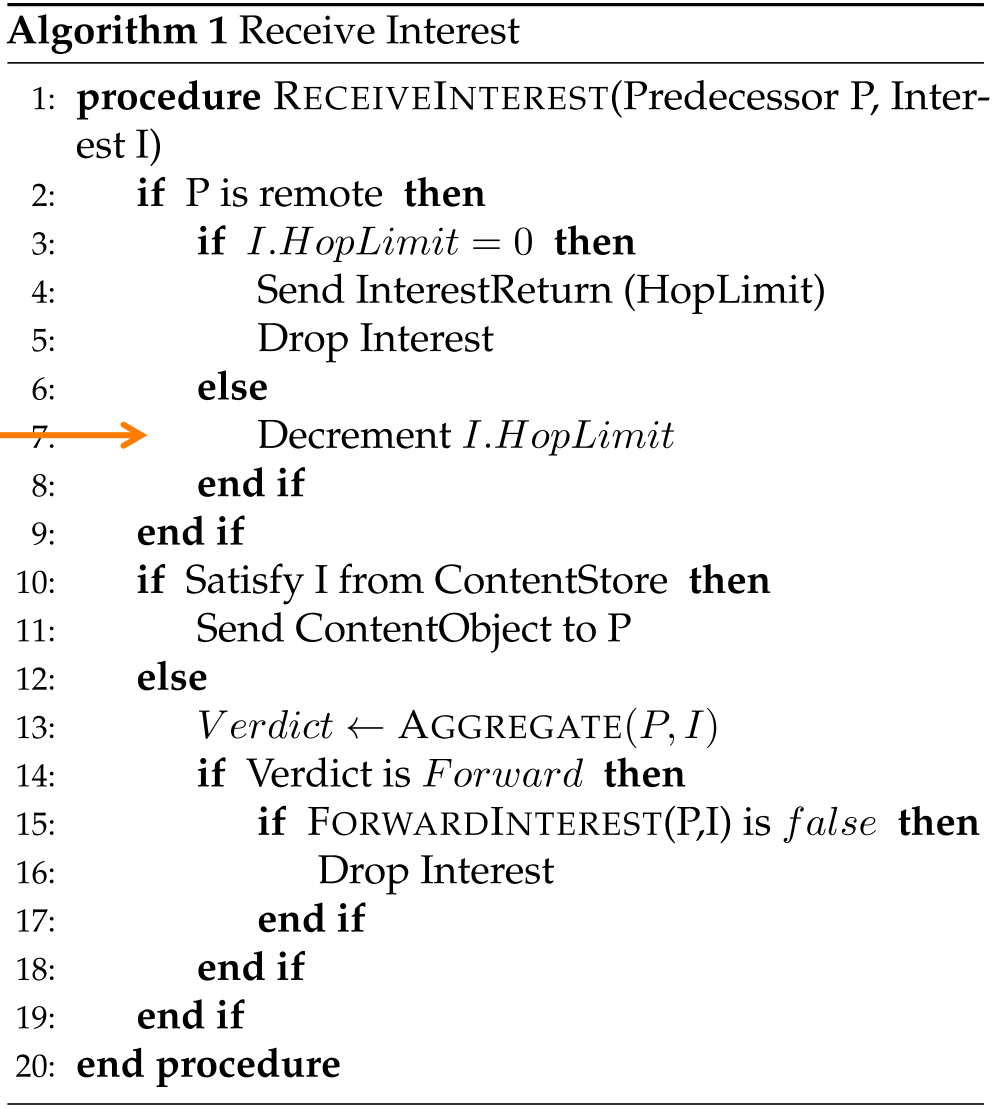
PROPERTY 6: CYCLE TERMINATION

- The **Cycle Termination** property is significantly different than prior CCNx 0.x and NDN cycle termination. In those protocols, because of the nonce, an Interest that visits the same node twice – assuming the nonce is remember long enough – is dropped.
- This means that such a node cannot continue using other paths, even if those will reach the destination.
- In CCNx 1.0, the cycle termination property means that an Interest will not repeat the same cycle, but it could be forwarded along another shorter path.
- Described in more detail in a few slides.

HOPLIMIT

- An Interest predecessor may be remote (i.e. another node) or local (i.e. an application connecting directly to the forwarder).
- The HopLimit indicates the number of allowed remote node hops.
- Forwarding to and from an application does not count as a hop.
- This semantic allows an implementation, if desired, to indicate “for me” in the FIB table via routes with a 0 HopCount, which is the notional model we use here. As this is internal behavior of a forwarder, it is not standardized.

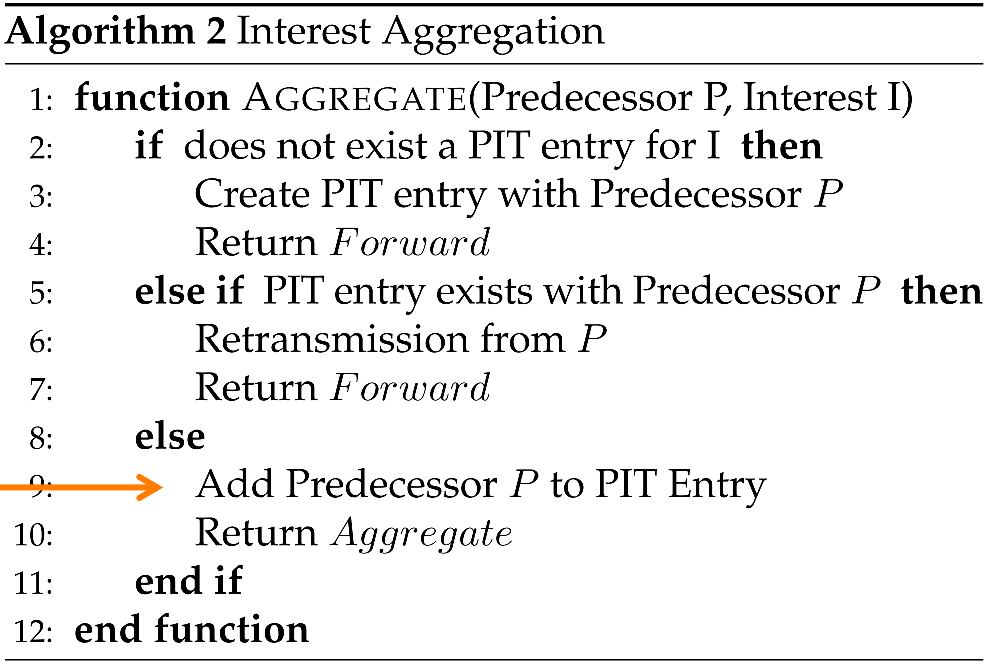
HopLimit must decrease each hop.



Algorithm 1 Receive Interest

```
procedure ReceiveInterest(Predecessor P, Interest I)
    if P is remote then
        if $I.HopLimit = 0$ then
            Send InterestReturn (HopLimit)
            Drop Interest
        else
            Decrement $I.HopLimit$
        end if
    end if
    if Satisfy I from ContentStore then
        Send ContentObject to P
    else
        $Verdict \leftarrow$ Aggregate$(P, I)$
        if Verdict is $Forward$ then
            if ForwardInterest(P,I) is $false$ then
                Drop Interest
            end if
        end if
    end if
end procedure
```

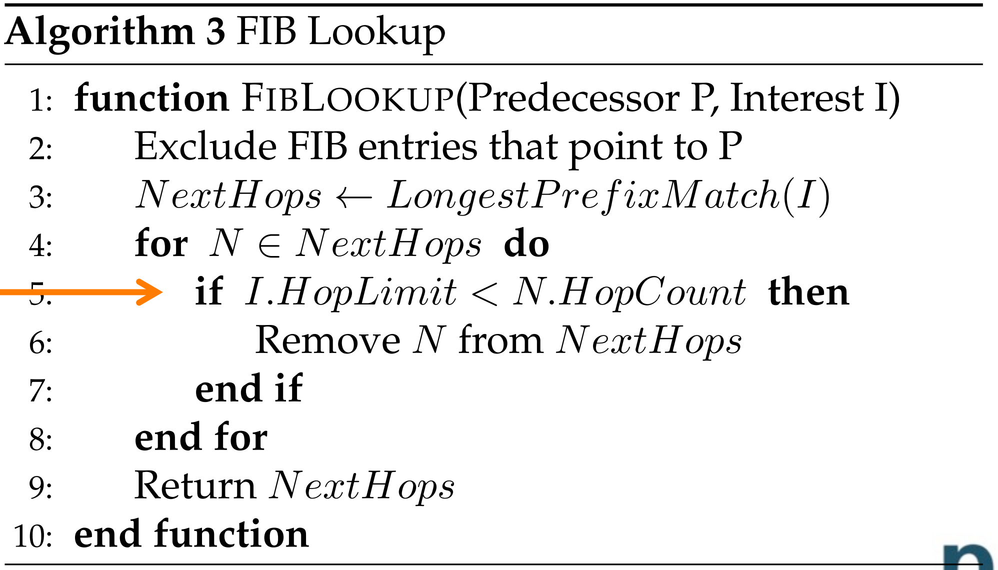
Only first Interest from a new predecessor for existing PIT entry is aggregated.



Algorithm 2 Interest Aggregation

```
function AGGREGATE(Predecessor P, Interest I)
    if does not exist a PIT entry for I then
        Create PIT entry with Predecessor $P$
        Return $Forward$
    else if PIT entry exists with Predecessor $P$ then
        Retransmission from $P$
        Return $Forward$
    else
        Add Predecessor $P$ to PIT Entry
        Return $Aggregate$
    end if
end function
```

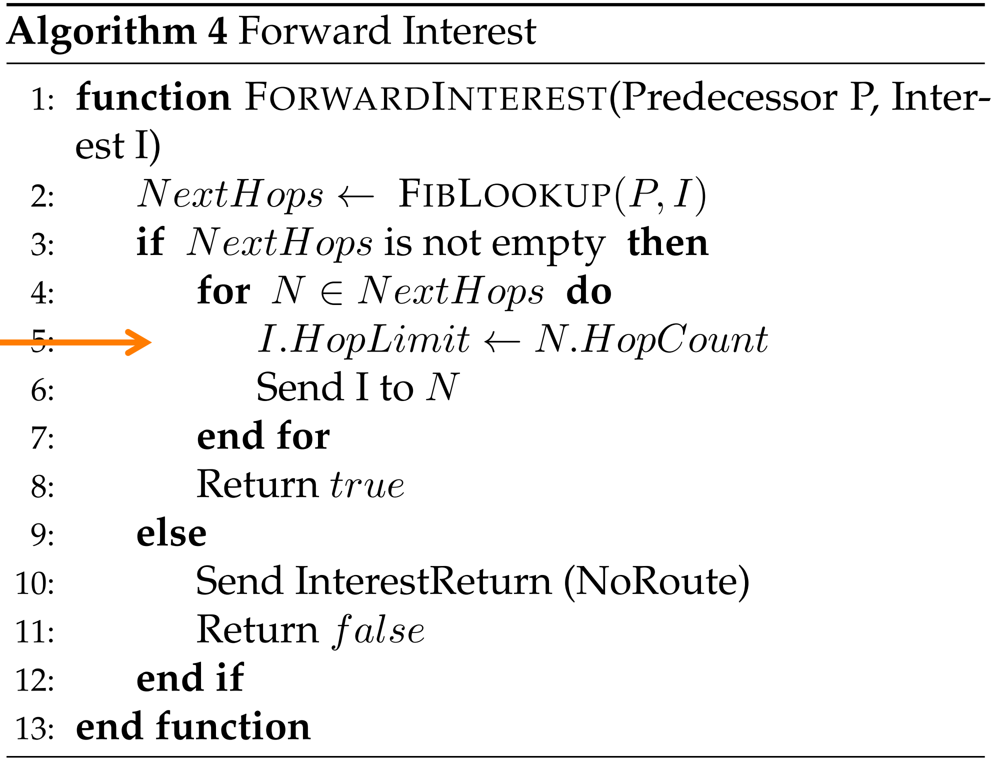
FIB hop count must not exceed the decremented HopLimit (Alg 1, Line 7)



Algorithm 3 FIB Lookup

```
function FIBLOOKUP(Predecessor P, Interest I)
    Exclude FIB entries that point to P
    $NextHops \leftarrow LongestPrefixMatch(I)$
    for $N \in NextHops$ do
        if $I.HopLimit < N.HopCount$ then
            Remove $N$ from $NextHops$
        end if
    end for
    Return $NextHops$
end function
```

Interest output has HopLimit set to the FIB's HopCount (which must be less than the input HopLimit, Alg 3 Line 5)



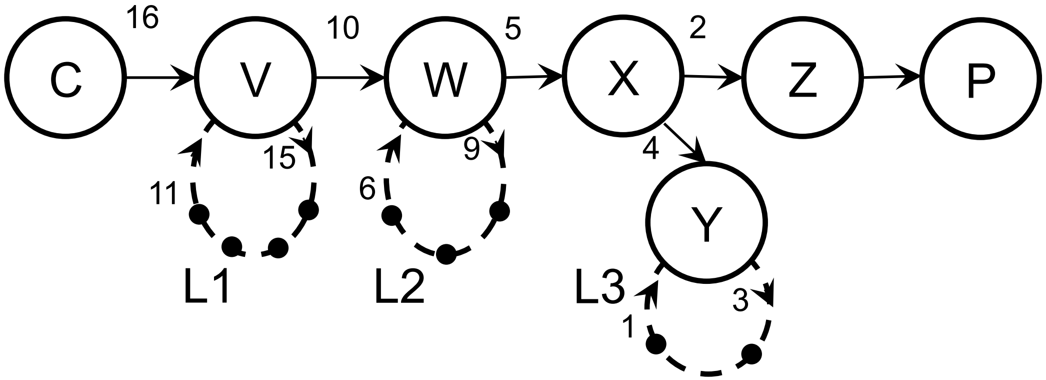
Algorithm 4 Forward Interest

```
1:  function ForwardInterest(Predecessor P, Interest I)
2:      $NextHops \leftarrow$ FIBLookup$(P, I)$
3:      if $NextHops$ is not empty then
4:          for $N \in NextHops$ do
5:              $I.HopLimit \leftarrow N.HopCount$
6:              Send I to $N$
7:          end for
8:          Return $true$
9:      else
10:         Send InterestReturn (NoRoute)
11:         Return $false$
12:     end if
13: end function
```

PROPERTY PROOFS

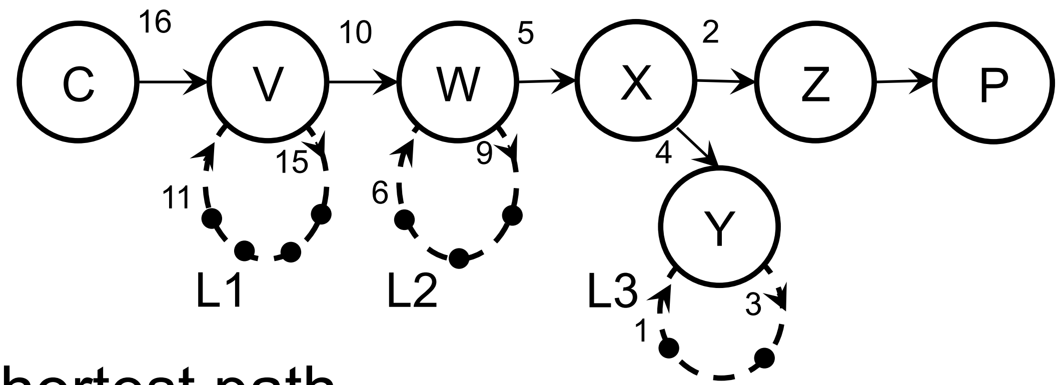
- Not presented here, written up in paper submission.
- Can sketch out the proofs in Q&A if you have specific questions.

CYCLES



- Use this topology for example.
- Assumes each forwarder uses unequal cost multipath.
- Numbers indicate the FIB HopCount of each successor.
- Interest sent from consumer C towards producer P.

CYCLES



- **C-V-W-X-Z-P**: The shortest path.
- **C-V-L1-V-W-X-Z-P**: The cycle L1 is permissible because the HopLimit will be 15 on entering the loop and 11 on exiting the loop, so the successor W is feasible.
- **C-V-W-L2-W-X-Z-P**: The cycle L2 is permissible because the HopLimit will be 9 on entering the loop and 6 on existing the loop, so the successor X is feasible.
- **C-V-L1-V-W-L2-W-X-Z-P**: As in prior two cases.
- **C-V-W-X-Y-L3-Y-{}**: The path via Y will terminate after the first cycle because the HopLimit on exiting L3 will be 1 and Y has no successor with a feasible HopCount.

CONCLUSION

- CCNx 1.0 Interest aggregation algorithm
  - Does not use timers.
  - Does not depend on the ARQ mechanism (nor does the ARQ mechanism depend on the Interest aggregation scheme).
- Has desirable properties
  - At most 1 interest forwarder if no retransmissions.
  - At most 1 ContentObject downstream per link, even with retransmissions (ignoring in-flight misses).
  - Interest will not travel a cycle more than once.