Semi-Centralized Name Routing Mechanism for Reconfigurable Network

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Abstract. Dedicated to overcoming weakness of current Internet architecture, some novel internet architectures have been proposed recently. Examples of these architectures contain Information Centric Networking (ICN), Name Data Networking (NDN), reconfigurable networking etc. As far as we know, the most efficient name based routing mechanism which suites the new architectures has not been found yet. This paper proposed a Semi-Centralized Name Routing (SCNR) protocol for reconfigurable network to enhance the routing efficiency. Results of this paper show that SCNR has good performance in ICN, which can be regarded as one of the many sub-networks in reconfigurable network.

Keywords: Name based Routing · Reconfigurable Network · OpenFlow · FARI

1 Introduction

The networking paradigm is shifting from communication between hosts to communication for data. The information-centric networking is one of the significant results of different international Future Internet research activities, which has been explored by a number of research projects, such as CCN [1], DONA [2] and NDN [3].

Flexible Architecture of Reconfigurable Infrastructure (FARI) is proposed and funded by one of National Basic Research Programs of China. FARI not only keep open, simple and robust features as tradition, but also follow some new principles such as interaction, variety and selectiveness. It is more than a simple expansion of current network or extension of telecommunication network, and it can also provide flexible, universal, customizable and variant network service. In other words, the target of FARI is to construct some sub-networks, e.g. Content-Centric Network (CCN), Name Data Network (NDN), Information Centric Network (ICN), Service Centric Network (SCN), traditional IP-centric network, and any networks which would be proposed in the future, in a single physical network by isolating infrastructure resource. For convenience, we propose an efficient routing algorithm over ICN, a sub-network of Reconfigurable network.

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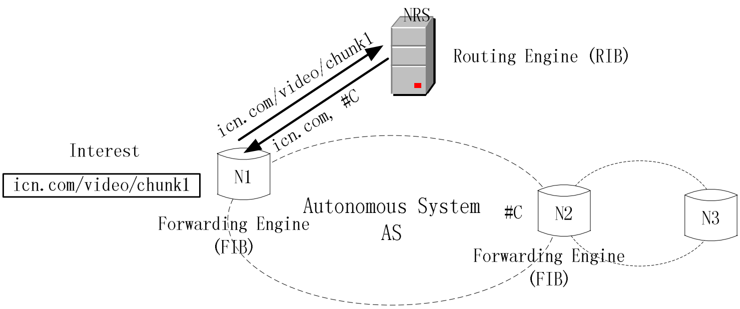
In this paper we discuss a Name data Routing based on Link State algorithm which is called Semi-Centralized Name Routing (SCNR) in sub-network ICN for FARI. We will refer the lookup-and-cache routing mechanism of Content Network (CONET) [4] architecture to design the SCNR algorithm, and deploy it in OpenFlow [5]. In Section 2, we describe the Lookup-and-Cache Architecture. Section 3 gives the design of the name link state routing. Section 4 gives the simulation results. Section 5 contains the conclusion.

2 The Lookup-and-Cache Routing Mechanism

The concept of lookup-and-cache is first proposed in [4], which is used to update CONET name-based routing tables. Because of the inefficient aggregation of names, the prefix-dissemination could produce big name-based routing tables. In order to support the above case, the lookup-and-cache is proposed, since it is not feasible to include all possible names in the routing table. In this method, a CONET node uses a fixed number of rows of its name-based *routing table* as route cache. When a node lacks of the routing info, it requires an interest packet to looks up its routing entry in a *name-routing-system* and inserts this entry in the route cache.

In this paper, we refer to the lookup-and-cache mechanism in SCNR algorithm to cope with the capacity issue of the FIB and with the cost issue of the RIB. We plan to use the FIB of a Reconfigurable node's Forwarding Engine as *route cache*, and to deploy a centralized routing system that serves all the nodes of an Autonomous System (AS). Fig. 1 gives an example of Lookup-and-Cache operations. Node *N1* receives an interest message for "icn.com/video/chunk1". When the FIB lacks the related route, firstly, the node temporarily queues the interest message, secondly, the node lookups the route in a remote RIB, and then gets the routing information and stores it in the FIB. In the following, we give the brief rationale underlying the Lookup-and-Cache architecture.



Name Prefix	Next Hop
...	...
...	...

Name Prefix	Next Hop
icn.com	#C
...	...

Fig. 1. Lookup-and-Cache concept

FIB as route cache, As we all know, the number of flows of Interest message is very large. However, the Reconfigurable ICN node concurrently route-by-name is even much smaller than ICN routes. Thence, the FIB is proposed as route cache, and contains the entire set of active-routes. When the FIB is short of a route, the node lookups the route in a remote RIB and then stores the route in its FIB.

Centralized routing engine, All routes are contained in the RIB of a routing engine in the NRS, which serves all the nodes of AS and runs on a logical centralized serve, named Name Routing System (NRS) node. Therefore, a single network device can replace all the network nodes, and this approach reduces the cost greatly for network operator.

[6] has described the "data-plane" of Lookup-and-Cache architecture. However, the Lookup-and-Cache architecture needs "routing-plane" procedures that runs on NRS nodes and whose goal is to setup the RIBs. This paper proposes SCNR and gives the collaborative design of SCNR algorithm in local reconfigurable ICN node and NRS.

3 Name Based Centralized Routing for Reconfigurable Network

The Name routing is deployed both in NRS Controller and reconfigurable ICN routers. [1] proposed Link-state Intra-domain Routing technique and also discussed about both IS-IS and OSPF for nodes to discover and describe their local connectivity and to establish adjacencies. This paper adapts the idea of IP OSPF protocol and develops SCNR over ICN.

The ICN nodes will advertise their adjacency and name prefix of the content in the network. Neighbors receive this advertisement and build Link State Data Base (LSDB) from the adjacency advertisement and forward it to NRS, and then the NRS calculates the routing table from the topology. When routing table calculation is complete, and the NRS has the Routing Information Base (RIB) of name prefixes. From this information, Forwarding Information Base of ICN node will be formulated, and the interest will be routed based on the FIB entries. Fig. 2 shows the SCNR internal constructing and algorithm.

3.1 The Operations of Router Booting/Rebooting Up

Router read configuration file as soon as it boots/reboots up. By reading the configuration file, the router sets the router-name, Name prefix List (NPL), and other configuration parameter, builds and updates Adjacency List (ADL). SCNR connects to a Daemon of reconfigurable routing node (SCNRD) synchronizing the Link State Data Base (LSDB) with NRS.

SCNR sends info interest to all the neighbors from ADL. If SCNR receives a reply for the info from neighbors then the status of the neighbor will be updated to "active" from "down" state. For any neighbor, if info interest is timed out in appointed times, then status remains unchanged for that neighbor. Neighbor's SCNR hear "info" interest replies with content containing information of its LSDB version and info version.

3.2 LSDB Synchronization

Two kinds of LSA are carried out by router, Name LSA origination and Adjacency LSA origination. Router reads the name prefixes from list, builds Name LSA and installs it to its own LSDB. Adjacency LSA is built by including the active neighbors from the neighbors list by checking the status of the neighbors. If there is any change in neighbor list status then router will build Adjacency LSA by including all the active neighbors and install the LSA in own LSDB. The LSDB synchronization is done in five steps as follows.

A. Sending LSDB interest

In the first step of LSDB synchronization, SCNR sends interest "lsdb", received from neighbors in exclusion filter, on name prefix for all the active neighbors in ADL including the last version of LSDB. In reply it hears from neighbors then performs the work described in subsection 3). But if SCNR does not hear any reply from any neighbors, it will try sending "lsdb" interest promissory times. If interest for any neighbor is timed out for promissory times, then that neighbor will be considered down, and SCNR will update its ADL accordingly and will also schedule building of Adjacency LSA.

B. Sending LSDB Summary by Neighbors

Neighbor's SCNR hearing interest for "lsdb" will check the version number. If the version number in exclusion filter is older than the version number of LSDB, the SCNR will prepare "LSDB Summary Content" with all the header information of all LSA and reply back to neighbors. On the other hand, if the version in exclusion filter is not older than the version number of LSDB, then SCNR will reply with NACK content.

C. Sending LSA interest

In this step, if SCNR gets NACK reply content from neighbors, and then does nothing as it is already synchronized with that neighbor. But if SCNR gets "LSDB Summary Content" from neighbors, then for every LSA header in LSDB Summary Content, first it will check its own LSDB for existence. Secondly if the LSA does not exist in LSDB then sends "lsa" interest to neighbors.

D. Sending LSA by neighbors

Neighbor's SCNR hearing interest for "lsa", will check its LSDB with header information provided in interest name, prepare content with LSA information and reply back with the content.

E. LSA installation

SCNR receiving LSA content from neighbor will install it into LSDB. Installation process checks whether LSA is new/newer or not. If LSA is new then it will be added into LSDB. If LSA is newer than delete old LSA and add the new one. However, if LSA is newer and is checked valid, then delete old LSA and install new one. If LSA is not valid, then delete the old LSA and discard new LSA.

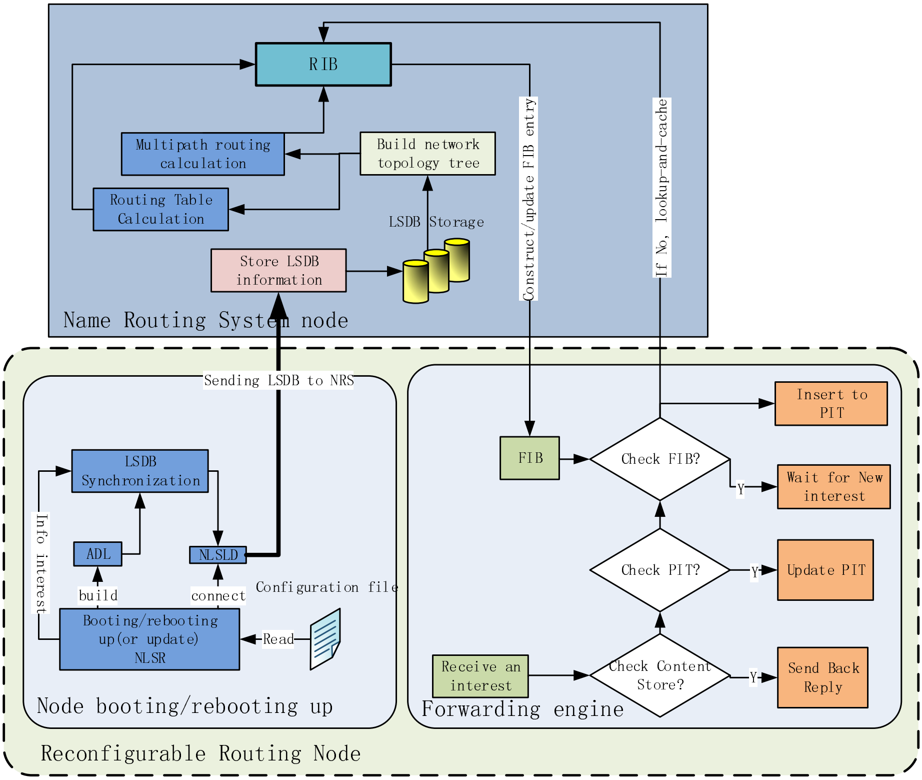


Fig. 2. SCNR algorithm

4 Performance Analysis of SCNR

The matrices used for comparing performance of SCNR are: success rate, routing overhead and end-to-end delay [7]. If a query acquires the requested content, that is called successful. The ratio of total number of successful queries to the total number of queries is defined as success rate. The higher success rate value means better result. The success rate (*Sr*) is written as:

$$Sr = \sum_{1}^{N} SucPkts \Big/ \sum_{1}^{n} ReqPkts \qquad (1)$$

The average time interval between the generation of request packet at a source node and the successful reception at the data source node is called end-to-end delay. It includes all possible delays, which may be caused by propagation, queuing and processing. The lower end-to-end delay value means the better result. The end-to-end delay (*De2e*) is given like follow formula:

$$De2e = \sum_{1}^{N} (SedTi - RecTi) \Big/ \sum_{1}^{n} RecPkts \tag{2}$$

The ratio of statistical number of routing packets generated in the network to the statistical number of request packets generated by all the simulated networks is defined as routing overhead. It reveals the utilization of the network bandwidth. The higher value of routing overhead means poorer throughput and longer delay. The lower routing overhead indicates a better result. The routing overhead (*Or*) is written as:

$$Or = \sum_{1}^{N} RouPktsN \Big/ \sum_{1}^{n} ReqPktsS \tag{3}$$

4.1 Simulated Network Assumptions

The simulated network comprises sixty routers, thirty HTTP traffic sources and ten data sources. All content stores were initially empty, and they got filled in with data as simulation continued. In this simulated network, this paper made following assumptions corresponding with [7] in order to facilitate comparison with SCNR.

1) The topology of the network is generated by manipulator software based on Power Law (Rank Exponent) distribution with r=3[8][9].
2) Traffic generation is an important part of the simulation. In this experiment, the appropriate traffic load is generated by simultaneously starting forty distinct content request flows.
3) The results of Sandvine's fall 2011 "Global internet Phenomena Spotlight" Survey showed that Hypertext Transfer Protocol HTTP traffic dominates Internet traffic [10]. Therefore, the HTTP over this simulated network will be taken.
4) The data networks traffic is characterized by extreme variability. In this experiment, the different heavy-tailedness of inter-arrival interval times is experimented by utilizing different values for alpha parameter of Pareto distribution for example 0.5, 1.0, 1.5 and 2.0.

4.2 Simulation Architecture and Results

As shown in Fig. 3, there are two planes in architecture of ICN network based on OpenFlow:

1) A data plane with the Serving Nodes (content producers), the End-Nodes (content requesters/consumers) and the Reconfigurable ICN nodes.
2) A control plane with the Name Routing System (composed by NRS Nodes). The two planes communicate with an extended OpenFlow interface, by using the NRS nodes to control one or more Reconfigurable ICN nodes. In this architecture, the NRS is responsible for name-based routing by implying ICN functionality as a set of OpenFlow controllers.

Table 1. Comparison of lookup-and-cache, flooding, expanding ring, random walk, alpha=1

	Success Rate (Sr)	Routing Overhead (Or)	Average End-to-End Delay (De2e)
Lookup-and-Cache	99.9	50	0.48
Flooding	99.9	268	1.10
Expanding Ring	99.6	231	1.09
Random Walk	99.9	141	0.79

Table 2. Comparison of Lookup-and-Cache, Flooding, Expanding Ring, Random Walk, Alpha=1.5

	Success Rate (Sr)	Routing Overhead (Or)	Average End-to-End Delay (De2e)
Lookup-and-Cache	99.9	32	0.29
Flooding	99.9	102	0.73
Expanding Ring	99.7	99	0.93
Random Walk	99.9	50	0.60

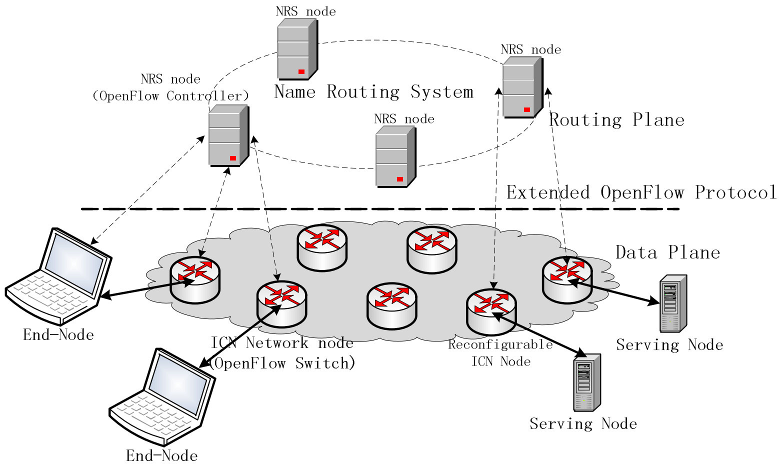


Fig. 3. ICN network based on OpenFlow

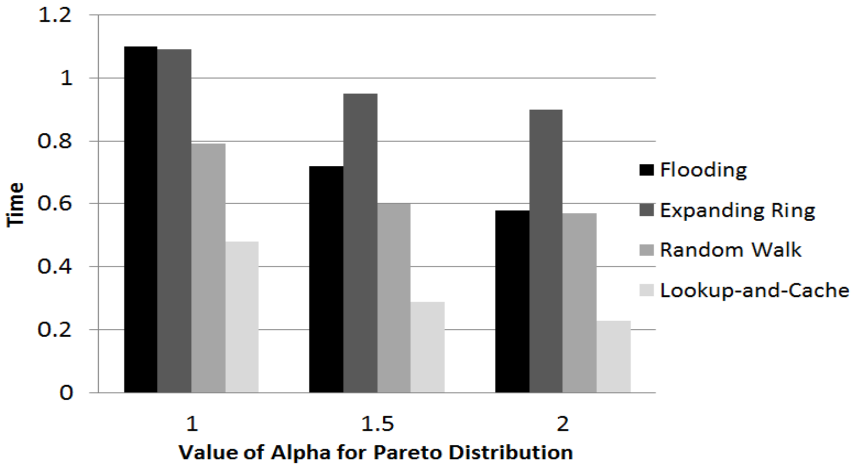


Fig. 4. Comparison of Averaged End-to-End Delay

The work of realizing ICN on OpenFlow, and its architectural in [6] can be referenced by us. Hence we focus on comparison of evaluation performance between Lookup-and-cache in SCNR and flooding, random walk, expanding ring presented in [7]. The averaged end-to-end delay behaviors of Lookup-and-cache, flooding, random walk, and expanding ring over two hours duration are shown in Fig. 4. We should note that the reconfigurable ICN nodes and NRS system needs a little time to initialize and configure. The RIB calculation in NRS will finish as soon as the nodes boot up, and subsequently the FIB stored in router's forwarding module will be constructed completely. Therefore the queries are satisfied from router's cache thereby reducing end-to-end delay greatly.

Tables 1, 2 give the comparison of success rate, packet overhead and end-to-end delay for lookup-and-cache, flooding, random walk and expanding ring for value of alpha equal to 1.0 and 1.5 respectively.

The simulation results show that the Lookup-and-Cache has the minimal routing overhead per request packet. The success rate of lookup-and-cache, flooding and random walk are comparable. The success rate of expanding ring is less than others, because the requested content cannot be accessed with initial TTL value with high probability. However, lookup-and-cache offers the smallest end-to-end delay followed by others.

5 Conclusion

In this paper, we implemented SCNR algorithms over OpenFlow and carried out a comparison with the similar transfer scenario of [7]. The SCNR algorithm separates the FIB from the RIB which is generated by calculating routing tables. This scenario can overcome two severe problems. First, the current FIB technology is impractical to contain all name-based routes. Second, the cost of implementing a large RIB in routing equipment is too high. Therefore the RIB-FIB architecture named lookup-and-cache architecture is an efficient solution to the reconfigurable network. The elementary simulation results of this paper show that, the lookup-and-cache offers the best performance over OpenFlow network.

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