A Taxonomy of Information-Centric Networking Architectures based on Data Routing and Name Resolution Approaches

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***Abstract*—This study presents a vast coverage of current Information-Centric Network (ICN) submission by evaluating eight distinct and popular routing and name resolution approaches. Internet build-up and initial deposition were based on a host-driven approach. With the increasing demands for media-driven data flooding the cost of the Internet, a new semantic and paradigm shift was envisioned known as ICN. Information-Centrism is an approach that partly dissociates the host dependencies by referring to contents by unique identifiers called name. However, to benefit from the content network, forwarding, naming and routing, among other issues are still in its developmental stages. The taxonomy serves as a basis for research directions, challenges, implementation and future studies for standardizing the ICN routing and naming. Routing and Name Resolution were themed in categories of strategies, contributions, issues and drawbacks. The major findings of this paper are providing a classification and review of the data routing and name resolutions approaches that are proposed on eight ICN architectures; presenting drawback areas in the selected architectures; and finally highlighting some challenges of ICN routing for the ICN research community vending.**

***Index Terms*—Content Naming; Data Routing; Name Resolution; Routing; Information-Centric Networking.**

I. INTRODUCTION

Originally, the Internet was designed to be an End-to-End (E2E) connection substrate for content delivery [1][2]. All the later enhancements developed for improving its architecture revolved about the discussion mode, which contains connections between equipment using the IP protocol. Nowadays, the Internet architecture is rapidly developing via interconnection of numerous networks. Simple vector represents the provision of the basic package delivery services without guarantees. Hence, researches are making outmost effort in trying to provide a media of receiving senders' requests and guaranteeing data from providers while using only IP addresses. Thus, to determine the endpoint of the forwarding of data and carefully considering what is being delivered [3].

In addition to that, the existing Internet content delivery today suffers from heterogeneity problems because its evolution and deployment to the current Internet architecture have been triggered by the market needs rather than the coherent Internet architectural plan [4]. Hence, these reasons have driven the shift from the current Internet architecture to a new architectural plan of the future Internet called Information-Centric Networking (ICN).

ICN represents a new paradigm shift in the evolution and definition of modern network protocols. It is a goal-driven approach to improve the traditional network operations by enabling ICN packet routing and forwarding based on named data rather than named hosts (IP address) for the communication model [5]. ICN has the potential to find a solution to several issues of the current Internet architectures, such as inefficient resource utilization, inadequate security, Distributed Denial of Service (DDoS) attacks [6], as well as mobility, scalability, routing protocol and economics (Alzahrani, Vassilakis, & Martin, 2013). Although the ICN is attained much popularity, but it also has many challenges such as caching, naming, routing and security [8]. Among all these challenges, routing is considered the most crucial component since it needs a flexible approach to decide how the packet route via the network.

The routing protocol specifies the communication between routers, which disseminates information that enables them for selecting routes between two or more nodes in a computer network, whereas routing protocols are decided based on the particular selection of route [1]. Every router has one prior knowledge only of the networks attached to it in direct connection. Hence, it shares this piece of information first with the immediate neighbors and after that to the whole network. In this way, routers get knowledge regarding the network topology. The routing approach represents the core for any ICN architecture. Therefore, the main aim of ICN routing protocol systems is for locating one or more copies of content that is distributed in the network [9]. The projects of ICN have suggested different solutions for routing such as name resolution and data routing.

Two major roles that must be in ICN intermediate nodes that receive sent requests for particular Name Data Objects (NDO) are thus: Firstly, it is a task with the discovery of node, such as, content server, which have a copy of this specific Data to forward the request to the node. While it can also be used to discover the route from the node to the subscriber on how the request for the data can be fulfilled. To achieve this functionality, one solution is through a name resolution by getting a layer or more lowers layers for an NDO name's locator. The locator can also be used to get the object. Another solution is to immediately route the needed request to the resulting node according to the syntax of the NDO's name, which is known as name-based routing. In this routing scheme, the name resolution step is somewhat omitted [10].

Although we could lay emphasis on many good survey papers for research on ICN (e.g. [11], [12], [13] and [14]), because of their broad coverage, however, there also exist few key points of re-visitation and coverage. The main goal of this work is to focus on routing in ICN architectures and describe routing approaches of eight representative ICN architectures. Furthermore, this work provides a critical analysis as well as presents their concepts and drawbacks of the important unresolved research issues of routing in ICN. Therefore, these issues need more attention from the research community. Finally, it highlights the main challenges related to the routing issue.

II. MATERIAL AND METHODS

In this section, we are classifying and reviewing the ICN architectures based on routing approaches. Routing approaches in ICN architectures can be themed into two different approaches: Name-based routing and name resolution [4]. These two approaches are handled by the routing of the NDO packet from its location-independent identifier in ICN [4][13]. Figure 1 illustrates the routing in ICN according to the approach.

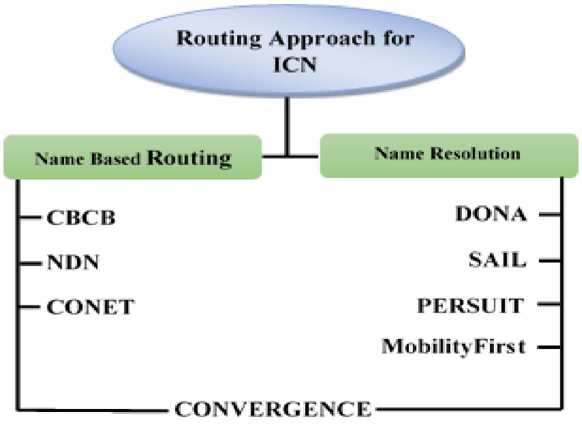

Figure 1: Routing Approaches in ICN Architectures

The name resolution approach consists of two processes: the first process is to resolve the content name to a single locator or a set of locators, while the second process is to route the requested message to one of these locators using the topology based on shortest path routing. Hence, this approach can guarantee finding NDOs node. On the other hand, name resolution approach may be a failure that may cause many indices to be unreachable even though the content is there [15].

Consequently, name routing approach forwards the request by as direct route based on the name (i.e. identifier) alone and sort the state information which setups the way for that requester. Content Routers (CR) are used in forwarding the NDO request. The CR locally determines, which is the next hop of NDO request relying on NDO name. In this approach, there is no guarantee to find NDOs. However, this approach provides a high expectation of discovering the content that is usually proportional to the number of visited nodes.

A. ICN Routing Using Name Based Routing Approach

This section introduces and discusses some representative information-centric architectures, alongside their routing management. There are many architectures under this approach which include Combined Broadcast and Content-Based (CBCB) [16], Named Data Networking (NDN) [17], [18], Content Centric Inter-Networking (CONET) [19].

a. CBCB

In CBCB architecture [16] routing information as it affects table and traversing is given by the protocol named CBCB. This is marked by a layer based on content that is deployed on a broadcast layer. This layer is charged with the duty of broadcasting and treats every message as a packet. Whereas the layer based on contents dynamically prunes paths of distribution thereby shaping the way in which the packets are communicated. It is the responsibility of the broadcast layer to ensure that every packet flow traversing through the sending node and to the receiver exhibit the best most possible shortest path and loop-free path. This implementation of the layer can be achieved using the loop-free topology mechanisms such as per-source trees, spanning trees and various techniques of diffusion.

CBCB propagates route-path information in two forms, which they are the Receiver Advertisements (RA) operation and a Sender Requests (SR) approach. RA is timely issued by the nodes and whenever a change is experienced, a resulting change occurs. The RA carries new predicates as well as propagates information to every probable content and provider nodes. This results in the need to create the needed routing operation for proper packet distributions towards the distinct nodes that received requests. When an RA received an advert, on a specific interface, it is bound to the content router to initiate a lookup on whether the address that is initiated had previously been served as an interface or predicate that it has been received. Then RA is directed to follow the instruction by RA as well as announce the filter that belongs to an RA emitter-centered tree. Accordingly, in the final stage, it handles the updating of the routing table by toting up the filters logically in RA to a receiving interface's predicate.

SRs are used by routers for gathering information regarding the current dedicated receivers, thereby enabling SRs to update their respective routing tables. Upon receiving an SR, nodes respond with a corresponding Updated Reply (UR). UR contains every predicate of its interface for communication. SR reception immediately implies the forwarding through all corresponding and needed interfaces in a resource oriented tree.

b. NDN

Is one of the pioneering approaches of the Internet architecture that predicts a new paradigm. It was initiated from PARC, which conforms to the ICN concept. Its essential semantics were thoroughly covered in an event of Google tech talk. This can be termed a longer idea delivery even before the initial CCN/NDN paper that attracted several attentions to the new architecture published. NDN architecture used two distinct kinds of packets, which are Data packet and Interest packet. Consumers are sending out Interest packet to request data-object that arrives in Data packet form, the two kinds of packet carrying the name of the requested data-object.

Every NDN node includes three data structures: A Content Store (CS), Forwarding Information Base (FIB) and a Pending Interest Table (PIT). Content Store houses the content and cache as a buffer. In NDN, it is not important for the user, to know the location of content demanded. It may be initially located on a single server (i.e., content publisher), but later and during the transmission over the network as communication progresses, the data keeps being stored (cached) in the cache of all traversed nodes. After caching the data, subsequent requests, for the same content Interest will only need to be forwarded from the nearest node that had previously saved a copy as the cache to aid a reply to the end user or endpoint requester.

FIB is equivalent to the routing table in the conventional IP networks that keep the IP addresses of the directly connected nodes and their related interface to forward the coming packets accordingly. The NDN FIB differs from one of the IP networks through an IP address prefix, which is changed with “Content Name” prefix while in NDN, the interfaces are changed with “face (s)”. The PIT is a cache table-based structure for Interest packet. The node sends the Interest packet that requests a content by forwarding to connect the node. It is designed to keep tracks of propagated Interest in order that they traverse back to Data by following these tracks for the consumers. Furthermore, PIT prevents multiple incoming request packets to generate multiple packet forwarding if the same Interests with many interfaces are received, only the first are pushed to PIT table, the other will be added to the interface entry number until the router received the Data packet.

The lookup and forwarding process for NDN packets is less complicated than in IP (see Figure 2). On receiving the Interest packet; NDN router lookup NDN's CS for one entry associated with the demanded content. If one of such entries is found, it is charged by sending the appropriate Data packet back. If it is not, the router checks for any pending Interest of the content in PIT. As such, the receiving part of the Interest packet is adding to the interface list for sending content into PIT, and Interest gets deleted. At PIT, in case there is no entry, the router forwards packet as per the rules of its FIB thereby creating a PIT record for the source interfaces.

In FIB, the task of forwarding interests and data is handled in the data structure. In an event that there is no entry for a particular content, no forwarding interface is therefore initiated, which interns make a match as invalid or otherwise. Such kind of instructions of routing intends to gradually find a matching node that would positively respond by sending the Data resulting packet in a backward path signaled to PIT entries in every hop crossed. Only one matched PIT entry results in Data packet forwarding with every other scenario resulting in packet disposal. Sources of Data are necessary in order to register specific intention of providing content via a register primeval instruction. Upon receiving a Data packet from an NDN node, the NDN node forwards the Data packet over all the requesting faces for a match in PIT entry and consequently, removes this entry from PIT when fulfilled.

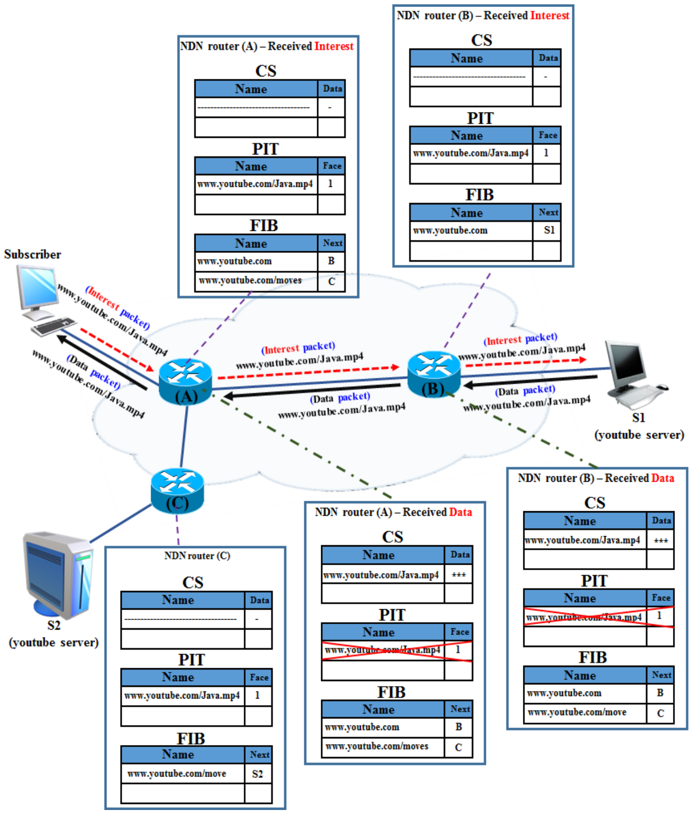

Figure 2: NDN Architecture

c. CONET

It is an architecture that proposes a new layer called CONET. It gives consumers the ability to access the network names’ resources, instead of remote hosts. The CONET intends to interconnect various CONET SubSystem (CSS) (see Figure 3) that can be of many forms: nodes are straight away linked as point-to-point (example seen in PPP); or IPv4/IPv6 networks; or a layer-2/ layer-3 network (example seen in Ethernet); or a UDP/IP overlay link. This fundamental idea makes CONET architectures scalable for deploying on the point-to-point links, and on the whole Internet or IP Autonomous System. CONET architecture is divided in form of a network with two layers; these are: CONET layer and under-CONET layer. The CONET layer is handled contents as a delicate as possible; whereas the under-CONET layer is concerned with links CSSs or nodes. CONET SubSystem deploys a handful amount of CONET nodes and makes use of an under-CONET mechanism for allowing data to flow between the layers.

All nodes have a CSS address that is consistently used by traversing nodes under the CONET technology (e.g. IPv4 or Ethernet MAC addresses). CONET nodes acquire requested contents by the issuance several requests known as interest CONET Information Unit (CIU), which in turn gives the receiving named data CIU as a response. In Forwarding to the consumer, CIU can be used as caches for future and subsequent requests as well. CONET nodes acquire their names after their CSS functioning.

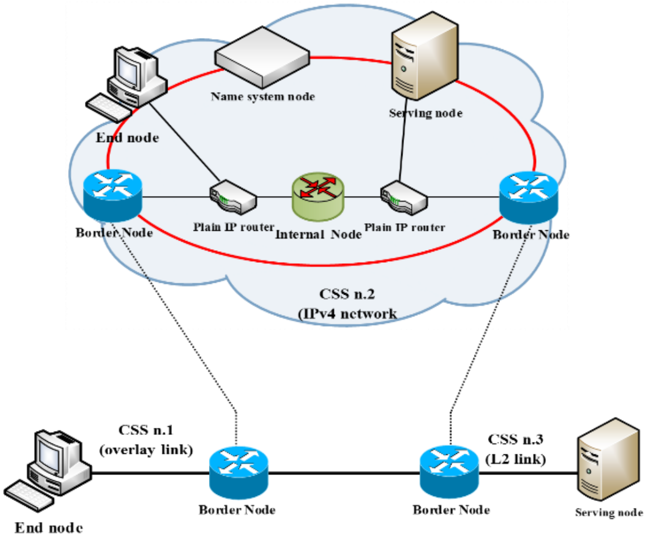

Figure 3: CONET Architectures

Accordingly, End Node (EN) requests content issues interest CIU, Serving Node (SN) store, provide and advertise content, Border Node (BN) linking various CSSs, and forwarding data CIU with interests among them. Thus, this acts as caches for data CIU, Internal Nodes (IN); which are optional to act within a CSS for providing in-network caches and finally the optional name System Nodes (NS). These are used in CSS name based routing operations serving as its mechanism. EN request's data via sending out interest CIU for a precise NID that is enslaved in one carrier packet, which is forwarded as per CONET based routing. The routing operation singles out the CSS specification of address on nodes coming to it and toward the best node that holds the needed data and suitable for it. Thereby, allowing this node to forward the request adequately.

B. *ICN Routing Using Name Resolution Approach*

This section introduces and discusses some representative information-centric architectures, alongside their routing management by using name resolution approach include Data-Oriented Network Architecture (DONA) [20], Scalable and Adaptive Internet Solutions [21], PURSUIT [22], and MobilityFirst [23].

a. *DONA*

DONA architecture is the ICN first architecture which drives the content centric approach based on a concept of a clean slate for persistent, content distribution and secure content naming. DONA uses name resolution approach, which implies that when the contents are requested, their routing is implemented from the special nodes known as Resolution Handlers (RH), as shows in Figure 4. “Name resolution is accomplished using the two basic primitives: FIND (***P*:*L***) and REGISTER (***P*:*L***)” [20]. The FIND (***P*:*L***) packet sends a request to the regional RH for locating a specific objects “***P*:*L***” This in return fulfills the RH forwards requests towards node that holds specific copies of the content requested. Nodes send REGISTER (***P*:*L***), desires for providing copies of the content, and establishes the essential state for RHs for effectively forwarding FIND a message. The Nodes are thus authorized by the principal to be able to send REGISTER (***P*:****) messages to their regional RH. As such, irrespective of the ‘***L***’ label that is initiated, all content requests under the ‘***P***’ key of the principal will be sent by the regional RH to the node that registered the “***P*:****”.

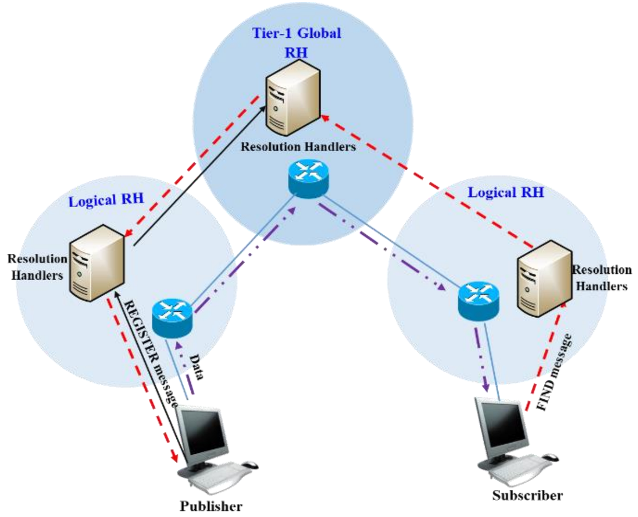

Figure 4: DONA architecture

In routing table, RH maintained different entries separately for “***P*:*L***” and “***P*:****”. This resolves a potential separate preceding hops for every entry. Moreover, the entries’ existence is essential in routing FIND messages to the content’s nearest copy. In this table, the absence of one entry enables RH to forward the FIND message to an RH node that is in a top hierarchy, gradually finding one valid entry in its routing table as top RHs focus on routing information from the RHs’ child nodes or from their sub domains. The FIND message is characterized with the insertion if it is in between the headers of the transport layer and IP, constraints to content address resolution. As such, traditional transport mechanisms get engaged for performing the delivery operation of content. Thereby just guiding those mechanisms that are named based without applying many changes in the resulting protocols and the infrastructure that supported it.

Automatic selection of server is set at one feature in a system of content distribution that is desirable. This exhibit supports in DONA natively. RHs forward the messages of FIND to its neighbor that is the lowest cost as per any selected delay metrics. Mobility as well as multiple-homing is also inherent to DONA. The FIND messages may be routed to one or more nodes by multiple homed RH paving way to the use of multipath for requesting content. Provision of mobility to end systems is under the responsibility of Content Registration Protocol (CRP) that is based on REGISTER and UNREGISTER messages.

b. *SAIL*

SAIL architecture is an implemented project work plan, which combines both detailed technical developments within the main technical objectives and other semantics. Moreover, it is achieved as a design for the future drive in Internet with ways to simplify a clearer transition paradigm from the existing Internet. SAIL is defined the “*ni://**A**/**L*** URI” scheme in that aids names containing an authority part ‘***A***’ and a local part ‘***L***’. Data routing and name resolution in SAIL architecture can be hybrid, decoupled or coupled. SAIL-decoupled, Name Resolution System (NRS) engages in mapping object names to locators, which can be utilized to reach the conforming information object [11]. The NRS is used as a form of Distributed Hash Table (DHT), either a Multi-level Distributed Hash Table (MDHT) [6] or a hierarchical SkipNet [24].

Each authority in the MDHT operation, manages each inherited local NRS by handling the resolution on the part ‘***L***’, while a global NRS is charged with the resolution of the part ‘***A***’. To achieve the availability of the information objects in SAIL, the part ‘***A***’ publisher forward a PUBLISH command message with its locator to local NRS that stores the part ‘***L***’ to a locator mapping. NRS is collected on all the parts of ‘***L***’ for the same authority part ‘***A***’ into a Bloom Filter (BF) [25]. This in turn sends the result to the global NRS a PUBLISH message.

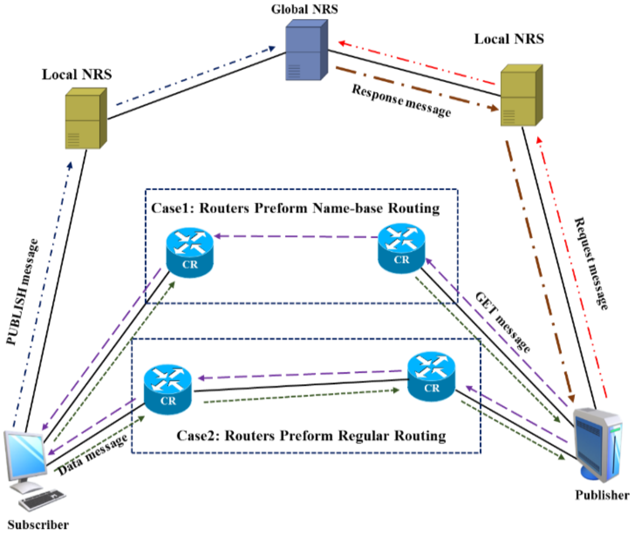

Figure 5: SAIL Architecture

The global NRS saves the mapping between the part ‘***A***’ with the BF and the local NRS, substituting any old mapping in his repository. In an event when the consumer (subscriber) requests any data objects, it can send a GET message to its local NRS which from the other side counsels the global NRS with a specific end goal to give back a locator for the data object (see Figure 5). The subscriber then forward the GET instruction to an end-user (publisher), by using the returned locator, and reaching out to a publisher with the data object encapsulated in a Data packet in the coupled state. The routing protocol is utilized to populate the entire routing tables of the Content Routers (CRs) and promote object names, as in NDN. The consumer sends the GET instruction to a local CR, thus, this increases it hop by hop towards the publisher or a cache [11].

c. PURSUIT

PURSUIT architecture differs in its context as it consists of rendezvous function, a topology management function and forwarding functionality. Each function separates its resulting action from the other functions. As shows in Figure 6, when the rendezvous operation matches a subscription to a publication, it guides the topology function administration to make a route between the publisher and the end-user (subscriber). This route is at least utilized by the forwarding function in performing the real exchange of information. Name Resolution is mapped by the rendezvous functionality, which is done through the collection of Rendezvous Nodes (RNs). The Rendezvous Network (RENE) diligently executed as hierarchical DHT. [26]. If the publisher wishes to put out some needed or requested information, he needs to exude a publish instruction for inherent local RN to be able to advertise the information object. The NR will then route the request to other RN in a corresponding manner using a scope ID.

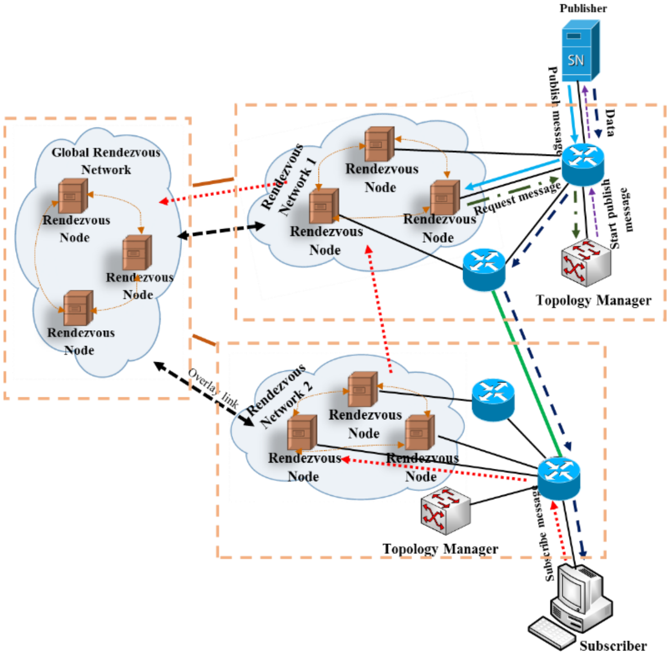

Figure 6: PURSUIT Architecture

Consequently, the subscriber needs to send a subscription message for this information object to its local RN. The subscribed message would then be routed using the DHT to the exact RN. The Topology Manager (TM) node, thus, then be directed by NR to establish a route that connects the publisher and the subscriber in order to deliver the requested data. The TM sends a route by a START PUBLISH message to the publisher in order to use the message to forward the information object by a group of Forwarding Nodes (FNs). The topology management function is implemented by the TM nodes in PURSUIT by executing a distributed routing protocol that detects the network topology [11].

The real delivery routes are calculated based on the functionality request and the function of rendezvous as connections between the FNs. These are prearranged into source routes using a method of Bloom Filters (BF) specification. In particular, every network node relegates a tag along a piece string delivered by an arrangement of hash function to each of its active connecting links. Which promotes these tags by routing protocol. A route in the network is instructed by the labels of its constituent connections, and the subsequent BFs are incorporated into every data packet. At the point when the information reaches the FN, the FN just adds the labels of its active connections with the BF in the packet; if matches are found, then the resulting packet is sent over the related links [27].

d. MobilityFirst

All connections in MobilityFirst architecture use a Global Name Resolution Service (GNRS) to translate the network address in one or more steps, as shows in Figure 7. When the publishers want to make the contents available, they ask for the naming service from the Globally Unique Identifier (GUID) in order to register it with its network addresses of the GNRS. Afterwards, GUIDs are mapped through hashing into a number of GNRS server addresses that may be contacted through the use of regular routing. Whenever subscribers are asked to receive data, it sends a GET packet, which includes the GUID from the requested object, together with its own GUID of that response to its intermediate node. It is only able to route based on actual network addresses. Therefore, it requests GNRS to obtain the mapping between destinations GUID and network address.

GNRS replies to the number of network addresses (maybe optionally; it will be sent to the source route, intermediate network addresses or an incomplete source route). Intermediate nodes choose one of these network addresses, adding the GET packet, and then it forwards using routing tables inside the intermediate nodes. The GET packet consists of both the destination network address and the GUID destination. All intermediate nodes on the route can be checked at the GNRS to obtain an up-to-date list of network addresses towards the destination GUID. In case there is mobility the GET packet cannot be returned to the publishers. They send its resulting responds to the subscribers' GUID, utilizing the same process.

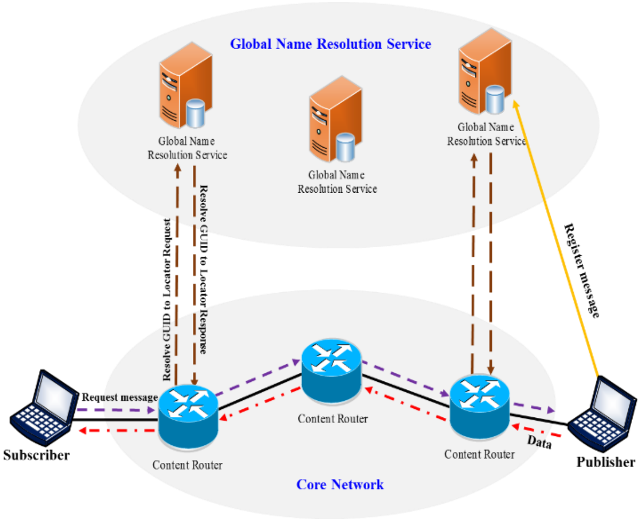

Figure 7: MobilityFirst Architecture

The routing is performed depending on the network addresses, where the GNRS is only used for mapping GUID to network addresses. For low dynamic services, MobilityFirst router can transform the GUID into a network address, as used in DNS, and function according to network addresses, which only require ignoring the GUID. Getting additional dynamic services, where GUID may be translated concurrently in larger times. Whereas the first router seeks the GNRS for the network addresses bound to certain GUID, which results in making forwarding decisions based on GNRS responding.

C. ICN Routing Using Name Resolution and Name Based Routing Approach

This section introduces and discusses some representative information-centric architectures, alongside their routing management. CONVERGENCE [28] is a an example for this kind of approach.

a. CONVERGENCE

CONVERGENCE building design has numerous likenesses with NDN project as its model has been executed as a modification of the NDN model. End-user (subscribers) in CONVERGENCE issues Interest packets requesting the data object, which is sent as crosses of hop-by-hop by the Border Nodes (BNs) to various distributors or Internal Nodes (INs) that performs caching (see Figure 8). From the other side, Publisher's reaction with Data packet, takes the reverse direction in granting the request. This is a specific end goal in decreasing the state requirements at the BNs. CONVERGENCE differs from NDN in three viewpoints. To start with, BNs don't use the information of the name-based routing for each advertised name prefix, it only utilizes a few portions of the information. Hence, the routing table is working as a routing cache. On the other hand, in an event that the Interest packets fail to find routing in order for the compared name that prevented the forwarding, BN counsels an outer NRS for the completion of the task, e.g., as seen in DNS, it is used to discover how to forward the Interest to a desired publisher [11].

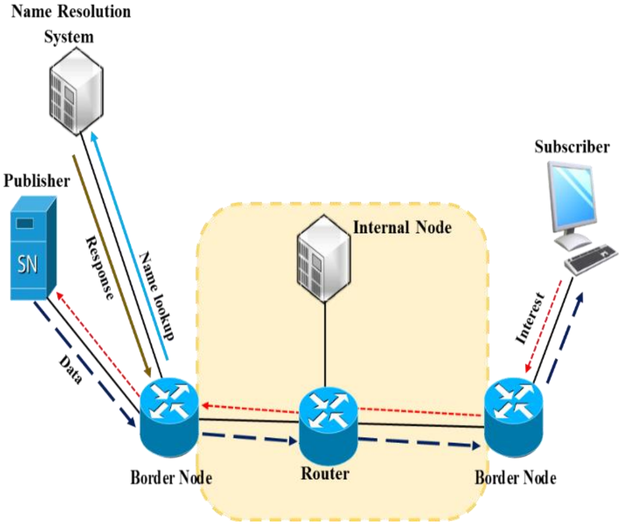

Figure 8**: C**ONVERGENC Architecture

The second point that differentiates the architecture, is that the Interest packets are distributed. They aggregate all the network addresses for the BNs that they cross, permitting the publisher to route the Data packet by reversing the order of information, without needing to maintain the pointers at BNs. The third point is the inability of BNs as they don't need to be directly connected. A typical setting between two BNs can include a number of hops. In this context, dissimilar to CRs in NDN; BNs binds names to network address instead of interfaces. NRS in CONVERGENCE can be also utilized when a suitable route is not found at some BN. Name-routing tables at BNs can be assumed to be mostly occupied without depending upon the NRS, or by running another routing protocol for name prefix, e.g., OSPF [29], as in NDN depicts CONVERGENCE building design.

III. RESULTS AND DISCUSSION

A summary in tabular form and a comparative study of these eight architectures is provided in this section as well as few open research challenges highlighted, which could be very useful for ICN researchers for smoothing the development of ICNs.

A. Comparison of ICN Architecture based on Routing Approaches

There is much information-centric architecture, which has been presented through the past few years. In this regards, this section analyzes in comparing, and contrasting the information-centric architectures that are depicted in Table 1. Selected research architectures supply a plausible reporting of the diverse research submissions toward routing request as well as the response in ICN.

B. Challenges of ICN Routing

Even though ICN is quite a new topic for researchers, many solutions and propositions covering a wide range of various issues under this topic have been done so far. Additionally, there are yet many challenges and solutions to be developed and deployment aspects that call for in-depth investigation. Routing is one of the main important research fields. The section highlights some issues in routing mechanisms, which are identifying a list of desirable properties for it.

- ***Scalability***: ICNs architectures must be able to serve a huge number of entities. Nowadays, the number of content in the Internet becomes huge and rapidly growing. According to [30], every ICN architectures need to be prepared for handling a minimum of 10^{12}objects, depending on the present size of the web and taking into account of an extremely conservative estimate. Scalability of ICNs routing approaches is main and more challenging for providing due to tow characteristics for these types of networks architectures, which are the difficulty to aggregate names and the expected size of the routing table.
- ***Discover the nearest copy***: ICNs architectures must employ routing mechanisms for disseminating messages to every node. Flooding is a basic as well as a simple approach that can do this. However, may result in increased in inter-domain traffic leads to high control overhead depending on the size of network. In order that, ICN routers must have an ability to route a content request to the nearest copy. This characteristic should ensure the inter-domain traffic reduction.
- ***Ensuring delivery***: ICNs architectures must be able to serve a large number of entities. In the Internet, the huge number of content objects led to many issues that may happen such as the flow control, congestion control and error control functions. Therefore, routing mechanisms must provide an ensure the delivery of all existing content in an efficient way with reducing delivery latency as well as guaranteed delivery of the packet to interested nodes only.
- ***Routing tables overflow***: ICNs architectures routing tables are very dynamic for all incoming request packet and matching data packet. Hence, a special process must be inculcated at these tables. These processes should have the flexibility for duties to be performed faster to avoid these tables from being overflowed. Resulting overflow would cause the delay and data loss for these packets. ICN approaches are routing tables, which are received and removed the packets exponentially. It is thus not easy to predict when the tables are full. This is also due to the high speed packet arrive rate to it. If the table is overflowed, consumers' requests will be discarded from the routers, and based on this; consumers will experience an increasing retransmitting rate that will lead to a complete collapse of the whole network.
- ***Content situation***: In both routing approaches name-based or name resolutions, it must provide low-routing overhead; metadata updates, avoids congestion, low-latency content operations (original or cached) registration and deletion. For that, none of each presented research architectures explicitly indicated content deletion or metadata updates. The interesting question at this point, how can determine the contented deletion for an expiry-time based or some hybrid or explicit.
- ***Security and filtering***: Limited researches and studies were done about the data security in ICN, especially in terms of routing mechanisms. One of these challenges are malicious users can create artificial requests in order to fill-up the tables on ICN routers. Hence, it is essential to implement a DDoS attack. This type of attack can possibly be implemented by distributing the generated request packets which include valid destination prefixes without existing resource names. In this order, routers can correctly forward requests and keep new entries inside the table. Nonetheless, replies never come back. Another issue of security in ICN architectures is the vulnerability of ICN in the cache pollution attacks. This type of attack includes sending random interests for content as a way to modify contents popularity. Thereby forcing ICN routers to store unpopular contents in their catches.
- ***Single point of failure***: All architectures that used the name resolution approach may suffer the single point of failure issue. Which could be as a result of when several NDOs are registered and published on NRS that is unavailable? This occurs when many nodes in the network become unavailable due to mobility. It thus may affect the QoS of the network for many applications (such as media streaming, interactive real time applications, file download). As a result, single point of failure is undesirable in each architecture in order of high availability or reliability.

Table 1
Comparison of ICN Architecture

Architecture	Year	Original	Strategy	Main Points	Drawback
CBCB	2004	http://www.inf.usi.ch/carzaniga/cbn/routing/index.html (University of Colorado)	Name based routing	Broadcast routing and content based routing using as a routing protocol. Supports Interest announced and Receiver advertisement packets. Supports content based forwarding table of data structure. Broadcasting for discovering alternate routing paths.	Required to broadcast, a huge number of messages for publish and subscribe. Routing tables want to handle about 108 routes. No guarantee of content discovery.
NDN	Sep 2010-Aug 2013	http://www.named-data.net/ (United States of America)	Name based routing	Search's hop by hop for object. Reliable, low latency, and global delivery. Supports Content and Interests packets. Supports CS, PIT and FIB tables of data structure. Discourages the formation of loops.	Link failures. Prefix black holing. PIT overflow. Congestion because of the PIT table size. Enormous complexity added to the process of route aggregation. No guarantee to the discovery of content. Scalability limitations in the "inter-domain level."
CONET	2013		Name based routing	Flexible architecture. Uses the name routing approach to update. Supports the content replication and caching effectively. Supports integration approach. Contains the tuple "(network-identifier, mask, next-hop, and output-interface)".	Scalability issue due to the CONET routing-by-name mechanisms. Complexity for implementing. Challenging when a Data packet is not verified
DONA	2007	http://www.sigcomm.org/node/2633 University California Berkeley	Name resolution	Resolution infrastructure consisted of RH. One logical RH for each domain. Supports operational primitives: FIND, REGISTER and PUSH. DHs propagate REGISTER request and route FINDs.	Global scalability challenge. Inter-domain paths problem. Single point of failure problem. Increasing routing overhead based on distance between consumer and publisher. Mesh-like inter-domain graph.
PURSUIT	Sep 2010-Sep 2013	http://www.fp7-pursuit.eu/ (Europe)	Name resolution	Uses in-packet BFs for source routing. Supports DHT-based rendezvous network. Routing structural consists of four parts; Rendezvous, Routing, Topology, and Forwarding. Supports SUBSCRIBER and PUBLISH messages. Supports DHT table of data structure.	Scalability problems. False positives because long path. Higher control overhead. Single point of failure problem. Inter-domain paths problem. Large storage for storing NDO mapping. Wasted packet transmissions.
SAIL	Sep 2010-Feb 2013	http://www.sail-project.eu (Europe)	Name resolution	Supports the decoupled, coupled and hybrid operations. Depending on a two level global and local DHT solution. Supports GET, DATA and PUBLISH messages. Supports MDHT and SkipNet tables of data structure.	Increased overhead. Single point of failure problem. Additional resolution steps. Scalability issues because of to handle a huge naming space which cannot be aggregated.
MobilityFirst	2011	http://mobilityfirst.winlab.rutgers.ed (Europe)	Name resolution	Supports hashing scheme for distributing the name resolution service. Supports Register, GET and Data messages. Support hash based global name table.	Additional resolution steps. Single point of failure problem. Slow to update the name resolution systems. Large storage for storing NDO mapping. The effect of changing the mobility and topology in the design of the name resolution system. Additional resolution processes.
CONVERGEN	Jun 2010-Feb 2013	http://www.ict-convergence.eu/ (Europe)	Name resolution and data routing	Supports data routing and name resolution approaches. Source routes are recorded during name resolution. Supports name lookup, Interest and Data messages.	High latency network-level, content replica, or content cached. Additional processes. Increasing routing overhead by data and request packets.

IV. CONCLUSION

This paper has attempted to put forward a survey of eight projects of ICN architectural and descriptive design for the future Internet concerning data routing. The paper has mainly focused on the two data routing approaches, which are, name resolution system and name-based routing. They are given a depth survey on how each one of the eight ICN architectures routing differs to its data depending on the mentioned data routing approaches. Hence, a comparison between these architectures in routing approaches was widely covered by identifying the originality, strategy, description and drawback of each concept presented. Moreover, we are highlighting a few issues based on routing concept for ICN architectures. In conclusion, specified data routing approaches will lead to having more efficient routing schemes, having additional practical significance in ICN designs that would drive the future Internet architecture. So our future work will be extended to cover more ICN architectures deeply.

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