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Named Data Networking (NDN): Fundamental Concepts & Benefits

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Abstract: Named Data networking is a project funded by NSF (National Science Foundation) under its Future Internet Architecture (FIA) Program. In 2006 Van Jacobson publicly presented the concept of Content Centric Networking (CCN) and it was a predecessor project for NDN. Its motivation is to solve the architectural mismatch of today's Internet architecture and its usage. Now the prime use of Internet as data or information distribution network not much match with an IP. In NDN a communication network allow the user to focus on data, i.e. named content, rather than the physical locations where the data is retrieved from called host. The NDN project aims to an evolution from host- centric-network-architecture (IP) to data-centric-network architecture.

Keywords: architectural principles; packet formats; security considerations; routing and forwarding; NDN testbed

I. INTRODUCTION

The hourglass architecture of today's Internet exists as a powerful design. It focus on universal network layer (IP) satisfies all the functionality necessary for worldwide Internet connectivity. Obstinate growth and usage of electronic commerce (e-commerce), other digital media, sites support social networking and smart phone applications has led to assertive use of the Internet as a distribution network. In distribution network solving problems via point-to-point protocol is difficult and error prone. NDN solves a broader range of problems like problems in end to end communication, content distribution and control problems.

The core idea behind NDN says, modern communication consists of request for named data but today's networks are based on host-to-host connections. NDN is a general purpose network protocol built on request for named data.

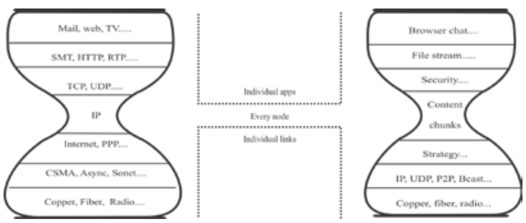

Fig: 1

The main building blocks of NDN architecture are named content chunks. In IP architecture the main unit of communication is an end-to-end channel between two end points identified by IP address.

II. NDN TEAM

ULCA: Van Jacobson, Jeff Burke, Lixia Zhang
University of Arizona: Beichuan Zhang
University of California, San Diego: Kim Claffy
Colorado State University: Christos Papadopoulos
University of Illinois, Urbana Champaign: Tarek Abdul Zaher
University of Memphis: Lan Wang
University of Michigan: J Alex Halderman
Washington University: Patrick Crowley

III. ARCHITECTURAL PRINCIPALS

- NDN follows the same hourglass shaped architecture that we used in today's Internet. This "thin waist" has been the main reason of the Internet's sustained growth.
- The end-to-end principle: Facilitates the development of strong applications in the aspect of network failures. NDN retains and magnify this principle.
- Built-in security: NDN provides the basic security by signing all named data at the thin waist.

- Self-Regulating Network Traffic: Flow balanced data transfer is necessary for stable network operation. NDN provides flow balancing in to the thin waist.
- Routing and Forwarding Plane Separation: Routing and forwarding is necessary for network development. NDN keeps the same principle with the best obtainable forwarding strategy.
- User choice and competition: NDN makes conscious effort to embolden end users and encourage competition.

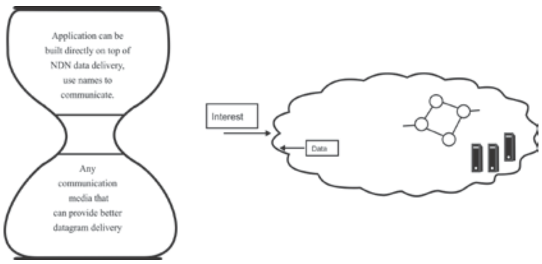

Fig: 2: Way in which NDN works

IV. NDN PACKET FORMATS

In NDN, communication is handled by the receiving end i.e. the data consumer by the interchange of two types of packets.

A. Interest packet
B. Data packet.

Here two types of packet holds a name that identifies the desired data and optionally a set of rules to determine which data content to return if more than one data object convenient to the Interest.

Interest Packet

Content name
Selectors (order preference publisher, filter...)
Nonce
Guiders (Scope, interest lifetime)

Data Packet

Content name
Metal Info (Content type, freshness period....)
Content
Signature (signature type, key locator, signature bits.....)

Fig: 3

Data consumers send Interest packets	Whoever has the matching data packet can reply

The name in an NDN packet can name anything i.e. an endpoint, a data chunk in a movie or a book or a command to turn on something. These names are generated by applications and are opaque to the network. NDN allows hierarchically structured names. It specifies the content relationship and facilitates aggregation. Every data packet carries a signature which binds the name to the content. NDN design allows hierarchically structured names.

Eg: A video produced by NSF have the name /nsf/videos/clip.mpg

Where / represents the boundary between the name components and it is similar to URL's.A simple set of selectors can support retrieving data with partial names.

Eg: A consumer requested for /nsf/videos/ clip.mpg and receive data packet named

/nsf/videos/clip.mpg/1/1

This is the first segment. The consumer then request for the later segments using the combination of information revealed by the first data packet and the naming convention of the publishing application. Content naming is an important part of NDN architecture, naming data helps to enable functionalities such as content distribution, multicast, mobility and delay tolerant networking.

V. SECURITY CONSIDERATIONS

TCP/IP leaves the responsibility of security to the end points, but in NDN it secures the data itself by cryptographically sign every data packet. The publisher signature is coupled with publisher information and it ensures integrity and enables determination of data provenance, allowing a consumer trust in data to be decoupled from how or where it is obtained. It also support fine grained trust allows the consumer to reason about whether a public key owner is an acceptable publisher for a particular data in a specific context. There are two types of trust models.

A. *Hierarchical Trust Model*-In this model a key name space authorizes use of keys for signing specific data.
B. *Web of Trust* - It enables secure communication without requiring pre-agreed trust anchors.

VI. ROUTING AND FORWARDING STRATEGIES

In NDN packet routing and forwarding is based on names. Which eliminates some problems arises due to the addresses in IP architecture. They are

A. *Address Space Exhaustion* - In NDN there is no address space exhaustion problem because the name space in NDN is unbounded.

B. *NAT Traversal*- NDN is away with addresses (public or private) so there is no NAT traversal problem. Finally address assignment and management is no longer required in local networks.

NDN uses conventional routing algorithms like link state and distance vector routing, NDN router announces name prefixes instead of IP prefixes, and it covers the data the router is ready to serve. Conventional protocols like OSPF and BGP is used to route on name prefixes by considering names as a sequence of opaque components and simply doing component wise longest prefix match of the Content Name from a packet against the FIB table.

NDN router maintains three data structures

A. *Pending Interest table (PIT)*
B. *Forwarding Information Base (FIB)*
C. *Content Store*

A router stores the interface from which the request is coming from and forward the Interest packet by using the name in its forwarding information base (FIB), which is populated by routing protocols that propagates name prefixes instead of IP prefixes. When the Interest reaches the node contains the requested data, the corresponding data packet is sent back. The data packet holds the name and data with a signature signed by the original data producer. The data packet moves in reverse direction formed by the interest packet and back to the consumer. NDN router keeps Interest and data for a period of time. If multiple Interests for the same data are received, the PIT stores all the Interest but only the first Interest is forwarded to upstream towards the data source. The PIT entry contains the name of the Interest and set of interfaces from which the matching Interest received.

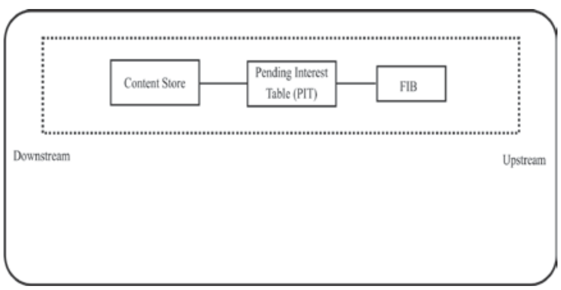

Fig: 4 NDN's node model

When the data packet reached, the router finds the matching PIT entry and forward the data to all interfaces specified. The router removes the corresponding PIT entry and cashes the data in the content store i.e. it is stored in the routers buffer with respect to cache replacement policy. Data go back with the same path that the Interest comes in but in the reverse direction. An NDN packet is independent of where it comes from or where it forwarded to. Thus the cashing process satisfied the future requests. It enables NDN to support different functionality without extra infrastructure contains content distribution, multicast, mobility and delay tolerant networking.

If there is no matching PIT entry, the router will forward the Interest toward the data producers (s) based on the information in the FIB entry and routers adaptive forwarding strategy. Multiple downstream nodes send Interest for the same name. The router receives the Interest but it forwards only the first one upstream towards the data producer. The FIB is populated by a name prefix based routing protocol and has multiple interfaces for each prefix. In some situations the forwarding strategy may drop the Interest for example if all upstream links are congested or the interest is suspected to be a part of DoS attack.

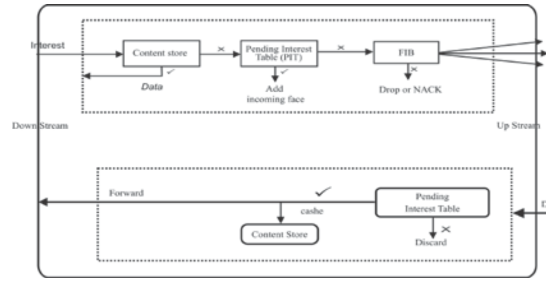

Fig: 5 Packet forwarding in NDN, 2 way packet flow, fetch, stateful with storage

×- lookup miss✓- lookup hit

Finally NDN's stateful forwarding plane facilitates

- Multicast Delivery
- Scalable Content Distribution
- Multipath Forwarding
- Closed Feedback Loop (it supports built in performance measurement at every router and Congestion control)

VII. GLOBAL NDN TESTBED

Global NDN testbed is a shared resource aimed for research activities, it includes software routers at many participating institutions, application nodes and other devices. One year ago, it includes 24 gateway router nodes, 9 of them are of sites of the NDN participating institutions. Remaining 15 at sites of collaborators and the presence is on 3 continents. Now two more new sites have agreed to join (in US and Austria) and it will make total of 26 nodes in 10 countries.

North America: 13 in USA

Asia: 3 in China, 1 in Japan, 1 in South Korea

Europe: 3 in France, Spain, Switzerland, Italy, Norway and Austria have 1 each.

NDN team develops a local testbed at Washington University during the first year of the project with programmable routers. There is a wide area testbed connecting all the participating institutions in the NDN project. The NDN team of Washington University manages operations of all nodes, all integration testing and deployment activities. It is funded by NSF and the NDN team support researchers to create their own testbeds. It accepts requests from external sites to connect to the NDN testbed.

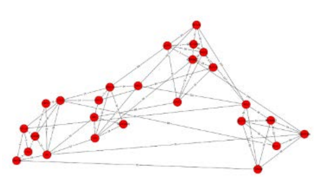

Fig: 6: NDN Testbed (26 nodes, 66 links with NLSR costs)

VIII. CONCLUSION

Internet has been a huge success but today's Internet hourglass architecture is no longer a good match to its primary use. NDN is new networking paradigm proposed the evolution from today's host centric network architecture to data centric network architecture. It generalizes the Internet architecture by replacing the focus on where endpoint addresses of hosts with what identifier of the content that users and applications care bout.

NDN is aimed to show

- Communication is more secure.
- Infrastructure is more efficiently utilized
- Applications are simpler
- new things are possible

It operates on top of the Internet protocols and it doesn't need a complete replacement of the current Internet architecture.

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