SCIENCE FORUM (JOURNAL OF PURE AND APPLIED SCIENCES) 22 (2022) 211 – 219

http://dx.doi.org/10.5455/sf.XXXXX

Science Forum (Journal of Pure and Applied Sciences)

journal homepage: www.atbuscienceforum.com

Connectivity framework for rendezvous and mobile producer nodes using NDN interest flooding

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ABSTRACT

Named data networking is one assuring instantiation of information concentric networking where emphasis is placed on content information of some vulnerable extent to some form of denial of service attacks. This problem is more severe especially during content transmission with minimum signaling and overhead costs on the global Internet. We adopted the use of an efficient protocol known as the listen first broadcast later for interest content as they are transmitted by the consumer in search for data between nodes of producer and rendezvous in motion. This framework can offer numerous advantages to real-time applications like video and audio using in-network caching and direct content forwarding. Simulation results in ndnSIM 2.1 and Wireshark present successful simplementation of the producer to rendezvous scalable content delivery between the links. This scheme ensures preventing attackers at both ends of the links without affecting non-attacking consumers and producers.

ARTICLE INFO

Article history:
Received 24 August 2021
Received in revised form
10 October 2021
Accepted 10 October 2021
Published 27 April 2022
Available online 27 April 2022

KEYWORDS

Connectivity
Interest
Data
Flooding consumers
Producers
ndnSIM
Wireshark

1. Introduction

Information concentric networking (ICN) is a network that permits real-time applications to connect with application-centric identifiers visible to the network layer entity. This means that identification can symbolize any packet, device, or service type. ICN packets or contents are exchanged by fetching, using unique names in the form of interest and data. A unique difference between named data networking NDN and Internet protocol (IP) is its ability to ensure multiple geographic locations' connectivity by temporarily caching data for future reuse. Mobile hosts in the NDN network can keep interest and data contents at their connecting point of attachment and can seamlessly connect and disconnect as they want during handoff processes. Content interests transmitted by a host at a single access point must be retransmitted when connecting to another new access point of another NDN network. This means that handoff has been successfully achieved and data contents can easily be returned back to the host as a reply.

2. Related Work

The efficient broadcast of an available content in a network by nodes is the basic requirement for implementation of new information-centric network architecture. In this research, we deliberate the issues involved in the implementation of an enhanced producer mobility management during such forwarding links/routes, interest and *data* content reachability,

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and delay tolerant networks that operate in an infrastructure-less network setup known as anchorless. These are some of the open issues that are progressively being assessed by nowadays researchers of ICN applications like vehicular networks, mobile Ad hoc Networks (MANETs), strategic military networks, disaster reliefs, etc. In spite of all these research efforts, there are ascetically limited studies in the domain of enhanced scalable and available data content transmission in NDN (Ahmed et al, 2019a, 2017b; Alzahrani, 2020).

Preceding research in both mobile IP and NDN is mostly inclined toward packets/contents being advertised when network infrastructure is anchored with an access point router or using content flooding. However, the concept of content flooding does not require knowledge of physical or logical location of any content in a network (Ahmed et al, 2019a, 2019b, 2017b).

In the architecture of information-centric networks, communication between entities is centered and enhanced on information retrieval instead of host-to-host communication scheme in IP. This literarily implies that content forwarding happens with respect to information not traditional hosts, while security is meant to control information not connectivity (Babiker et al., 2017). The NDN scheme is the most promising ICN architectural implementation that has tremendous backing. The router's forwarding information base (FIB) informs its connecting host to forward *interest* request using matching names on the Internet to easily identify *data* for a seamless reply. During routers advertisements, interest moves via the network in a breadcrumb path in a router's pending interest tables (PIT). As the reply is secured from either a rendezvous server or a producer node, it also passes through a router's PIT as a reverse-path technique of mobile routing. Table 1 presents the relevant literature that discuss and analyze scalable mobile NDN routing (Alawi et al., 2012).

3. Methodology

In this proposed NDN network, when a consumer (a mobile producer in acting capacity) achieves handoff, it simply sends a new *interest* message from its current position for the undelivered information object. Its PIT then holds the messages of the initial content router from both route paths for delivery. These route paths are paths that exist during and after handoff. This means that the corresponding information objects will be delivered to its original location before handoff. However, when a producer achieves handoff, the nearest path record in the FIB will be updated. This requires re-advertising the prefix name of the object on the entity using the routing protocol. This approach makes the NDN network face higher overhead during higher mobility situation. Therefore, the use of listen first broadcast later protocol can best implement our proposed scheme. Using this protocol, content interest gets flooded in the network and hence when a potential entity source tends to transmit contents, it waits for the channel of transmission (usually wireless) to detect if another subscriber node has earlier transmitted similar name content. If otherwise, data content is transmitted back as a reply using the same outbound link as the inbound link to the subscriber node.

3.1. Implementation

The proposed application of producer mobility support in an NDN network will be built using ndnSIM 2.1 and python bindings designed to be used in CCNx repository.

The performance utilization of the producers PIT is measured to soften and minimize its overflow using pending interest table control management (PITCM) as used in Ahmed et al. (2017a). The PITCM service approach manages incoming content interest from the producer node by softening its PIT against overflow and also improving its utilization as well performance.

To ensure available and scalable NDN connection in the proposed model during handoff, the mobile producer seeks contents from a destination of wither a stationary rendezvous server or mobile via a directly connecting access point as a consumer. This content request is transmitted as an interest packet. Here, when the content name transmitted is found at the access point record, it will successfully notify or else the content *interest* name that was not found will then flood the over-the-network setup. When the *interest* is found, it travels via all router links with the lowest cost based on the proposed algorithm until the intended producer received it. When the producer is realized, it is expected to reply to this request; data content is then sent back using a path with the lowest cost to the producer that acted as a consumer initially.

This successful communication will initiate handoff of the producer by disconnecting from its current access point to a new access point location in a different network. This form of mobility is known as inter-session mobility. In the new network after successful handoff, a new prefix will be attached to the content *interest* meant for the mobile producer for global routing updates. Using the routing protocol

Table 1. Summary of related research.

Author	Contributions	Results	Limitation
Alawi et al. (2012)	Proposed scaling one router node for the entire network. Scaling offers multiple connections where the protocol can cover all the existing routes in the network	Presents ways to achieve multi-homing for scalable NDN network	Could not implement decentralized servers to ensure seamless network scalability
Alzahrani (2020)	Assess ICN as an efficient scheme that can be used in IoT environments to address network mobility challenges.	Present scalability challenges of exploiting ICN as a communication enhancer for IoT mobile systems	Could not but recommends IoT network be implemented in mobility-centric situation such as frequent information on forwarding situation and keeping distributed caching and processing characteristics
Yuan et al. (2017)	Proposed NDN disaster management as a tool where a producer transmits fire alert information to connecting consumers in their network. The transmission makes the NDN routers converge based on the disaster location seamless and securely.	NS-2 results were shown using timed automata-based transition machine and model checker. The proposed framework present a less end-to-end latency of between 2% and 10% and decreased to 20% energy consumption while energy enhancement between 3% and 20% as compared with an NDN DMS	Suggests conducting research in different critical situations
Nour et al. (2019)	Proposed a hybrid scheme that adds the two worlds of IP to keep network topology and depend on NDN for content resolution and distribution	Result of investigation presents hybrid design for data delivery ratio rises between 250% and 300% when compared to NDN or IP	Recommends using emulator for future to verify the results

configured in the network, the access point then transmits updates with the new name added to its list for other FIB records. The routing plane of the access point in the network then uses the network availability algorithm with best route forwarding scheme to follow the shortest forwarding route and transmit the pending contents in its PIT of new location of the producer.

3.2. Topology

3.3. Mobility model

3.3.1. Random waypoint movement (RWP)

In the proposed scheme, RWP model is used. This involves the use of pause time when the producer tends to achieve handoff in term of direction and its speed in motion. The RWM scheme is usually an efficient approach that is used in many simulations for mobile *ad hoc*. To ensure scalability using RWP movement model (Fig. 1), producer nodes will be set to achieve move randomly in motion by assigning coordinates, speed, and route direction. During handoff, the destination is reached using a uniform motion between (0,Vmax). During coordinate assignment, no preconditions are set at the simulation phase. As the producer traverses between access nodes and arrive a certain destination, it stops for a short period which is already initiated in the beginning of simulation as pause time (i.e., Tpause). At the moment pause time becomes zero, no mobility is expected by any node and other entities. This will then automatically initiate another node in the queue and repeat the same steps as above. This process hence continues until the simulation time is completed.

3.3.2. Routing interest and data and name prefix resolution

When an *interest* is transmitted in an NDN network, the retrieval using *data* content is the most crucial task. Two routing techniques are used due to their worldwide acceptability. These techniques are flooding-based and distributed hash table (DHT). The DHT technique consists of levels that reflect the network topology using prefix name aggregation to minimize control overhead by enhancing network robustness.

3.3.3. Congestion control

NDN has the ability to convert end-to-end Transmission Control Protocol (TCP)/IP transport layer into receiver-based connectionless NDN stack layer of transport. As compared to TCP/IP, the NDN transport layer consists of features such as receiver based, one-Interest-one-Data, multi-source, and multipath. These are some open issues in the research domain.

3.3.4. On-demand content at runtime

On-demand NDN packet refers to an Interest packet transmitted by either a producer or consumer when it intends to achieve handoff in inter- or intra-network mobility interval. At the moment of request, it is yet to be advertised on the global Internet for network entities to grasp during mobile session. The producer node transmits a request of Interest message by tagging a prefix and coordinates for location information. Any connected rendezvous server in the network and point of attachment occupying the coordinate will be able to receive the content message and generate another content message so as to match with the interest sent and then reply back as a Data to the producer. This ensures availability and robustness of the network and is explained in detail in Algorithm 1.

3.4. Simulation

Simulation for NDN network scalability is conducted using ndnSIM 2.1, NS3based in Linux OS. In the network setup, 11 mobile producer nodes are deployed whereby routing announcements are received using link state algorithm approach. In the scenario, the producer node transmits interest content (video application) to the rendezvous server. In the topology, there are six rendezvous servers that are distributed between two networks but under one autonomous system. The request will be granted to the mobile producer after the video content is located, then transmitted back using lowest path signaling cost. Here, the network will take into cognizance the packet losses it will experience and the latency it will take to deliver that video application as before the producer achieves handoff. After all these processes, when the producer achieves handoff (i.e., from one network to another under same autonomous system), it ensures that scalability and availability are achieved within minimum rate of transmission and latency (Figs. 2–4).

4. Results

The performance result presents improvement on standard NDN router's PIT with 48% rate of better content satisfaction, 80% rate of content interest transmission, and 67% rate of interest drop rate. Also, the length and *interest* satisfaction latency are minimized adequately to 47% and 35% individually. This means that the designed framework can be implemented on a test bed successfully. Finally, the framework can offer numerous advantages to real-time applications like

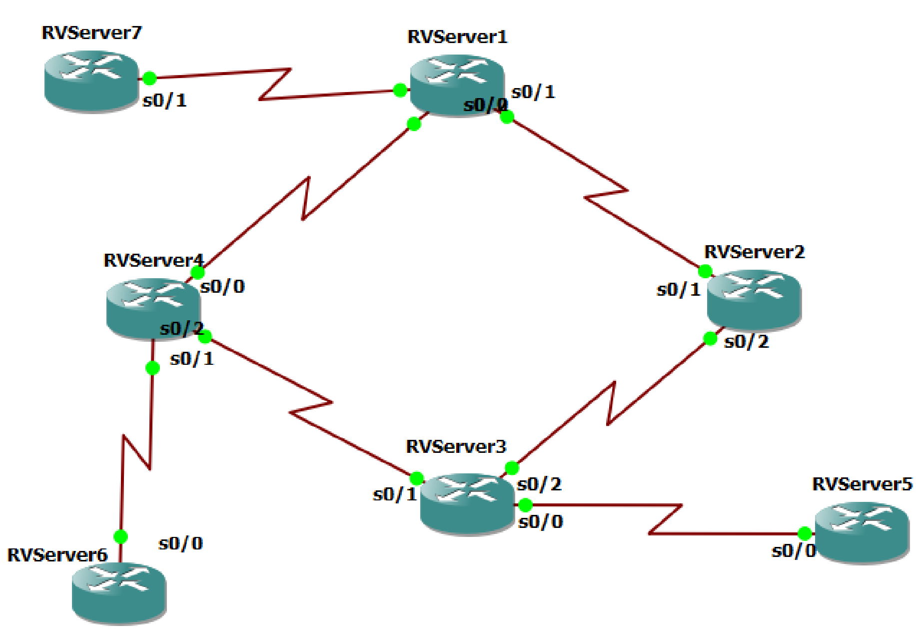


Figure 1. Distributed rendezvous nodes for scalability.

Algorithm 1. Network Connectivity during and after handoff pseudocode

Input: Mobile producer registration after handoff and content transmission to rendezvous server or next access point.
Output: Locating access point during/after handoff and link selection using unique prefix name

1: Case event
2: If the received signal strength is less than network threshold –77 dBm;
3: Obtain velocity of producer using mobility speed (v_{new}) and direction (u_{new});
4: Compute next handoff of producer coordinates (a_p, b_p) using producer's new speed and direction;
5: Producer transmit interest message as interest_u1 to connecting access point then return data;

6: While c:
7: Obtain computed producers coordinates (a_p, b_p) from transmitted message INTEREST_PU
8: Compute new access point using the expression:
9: Distance = sqrt (accesspoint$_p$ - a_p)^2 + (accesspoint$_p$ b_p)^2 // formula for distance between two points
10: Access point after handoff = minutes (distance)
11: New access point = access point after handoff
12: Return new access point
13: Transmit data content to new access point
14: Create copies of data content for limited session timeout (c_s)

15: If d
16: Re-transmit data content using new access point unique prefix name in d
17: Remove the copies of data contents after time (c_s)

18: else
19: return NACK //producer cannot transmission data content

video and audio using in-network caching and direct content forwarding.

For enhanced end-user's quality of experience, the real-time network application (voice and video) service can employ the Dynamic Adaptive Streaming over Hyper Text Transfer Protocol (DASH) approach in the NDN network. But employing the DASH approach in the NDN network may create the following issues:

In-network caching, which affects the content download period by creating issues of bitrate adaptation on large network applications.

Interpreting similar segments of application can also exhaust cache storage and cause caching inefficiency.

These issues can be solved using bitrate adaptation that is a congestion-based closed loop from the connected intermediate producer nodes. Hence, other researchers present this approach as not the only solution to this caching challenge for multiple bitrate real-time network applications.

The results are captured from Wireshark after interfacing with ndnSIM 2.1 for time intervals of 30, 120, and 210 seconds versus number or amount of contents at less than 420 and 480 seconds. The results are shown in Figures 5–10.

For the sequence number, it exploits the transport control protocol using *interest* and *data* link labels for

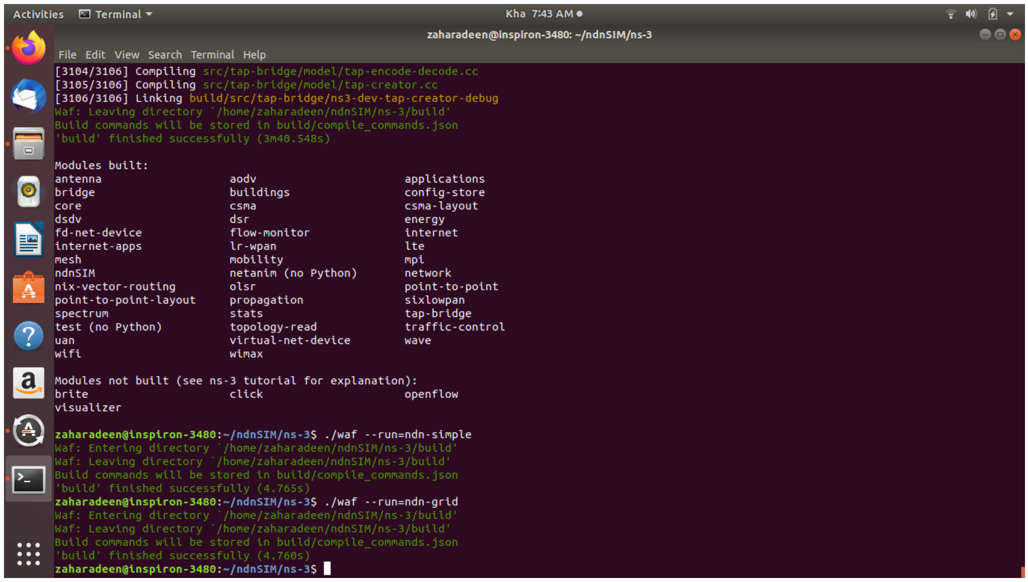


Figure 2. Simulating the network topology.

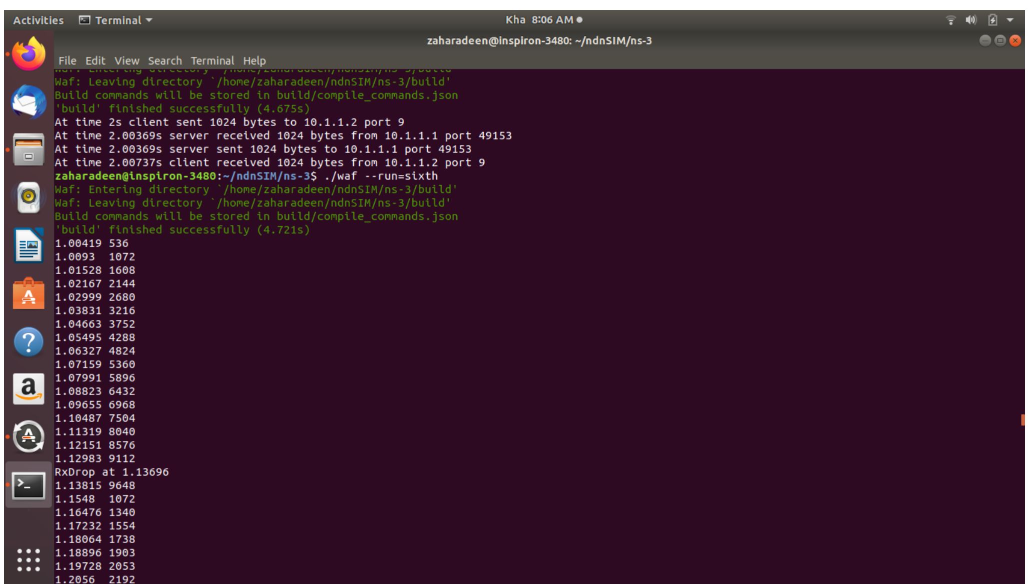


Figure 3. Run simulation for the scenario.

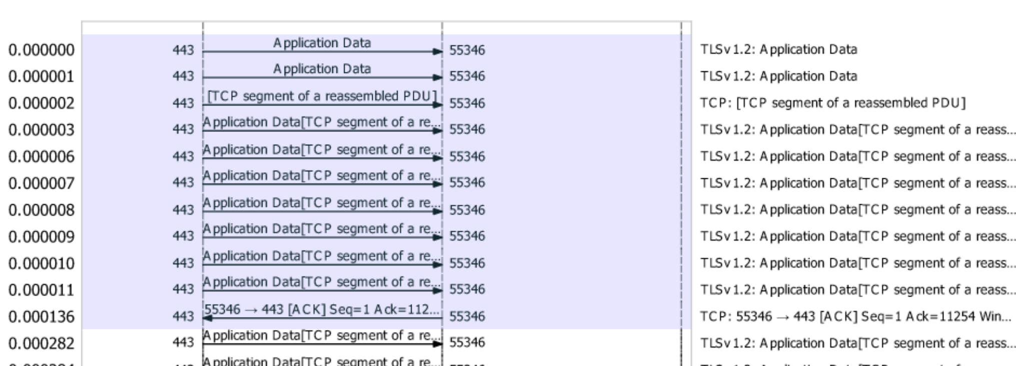


Figure 4. Flow graph for the network.

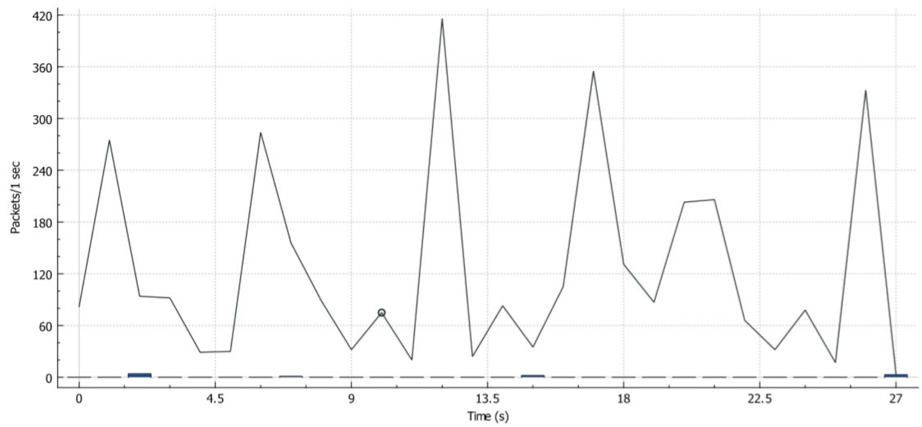


Figure 5. Inbound and outbound content movement between producer and rendezvous.

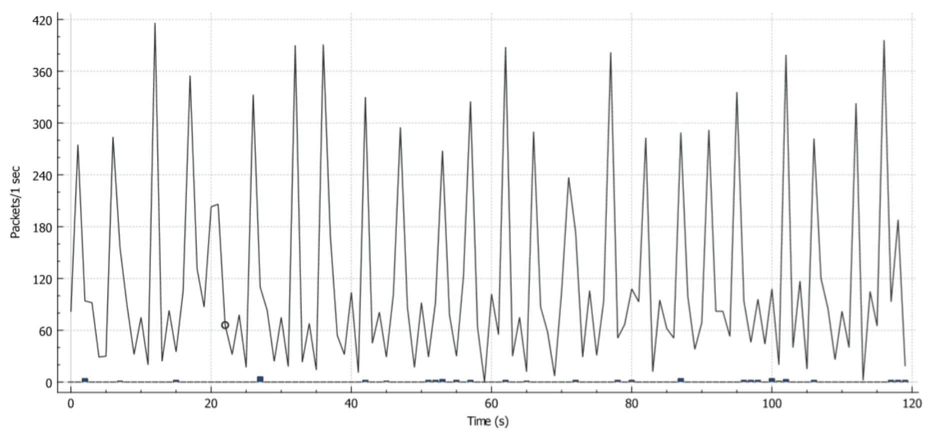


Figure 6. Inbound and outbound content movement between producer and rendezvous. The congestion continues to increase but is controlled due to the presence of the flooding-based protocol being implemented to handle content control during transmission between rendezvous and mobile producers.

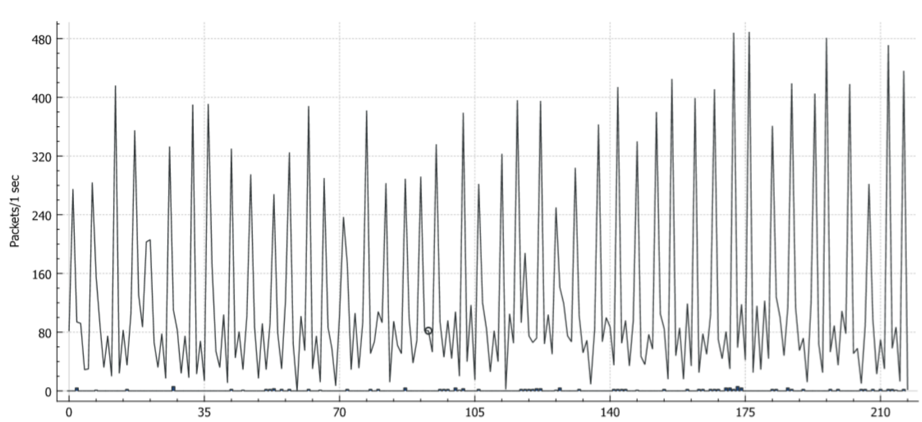


Figure 7. Inbound and outbound content movement between producer and rendezvous.

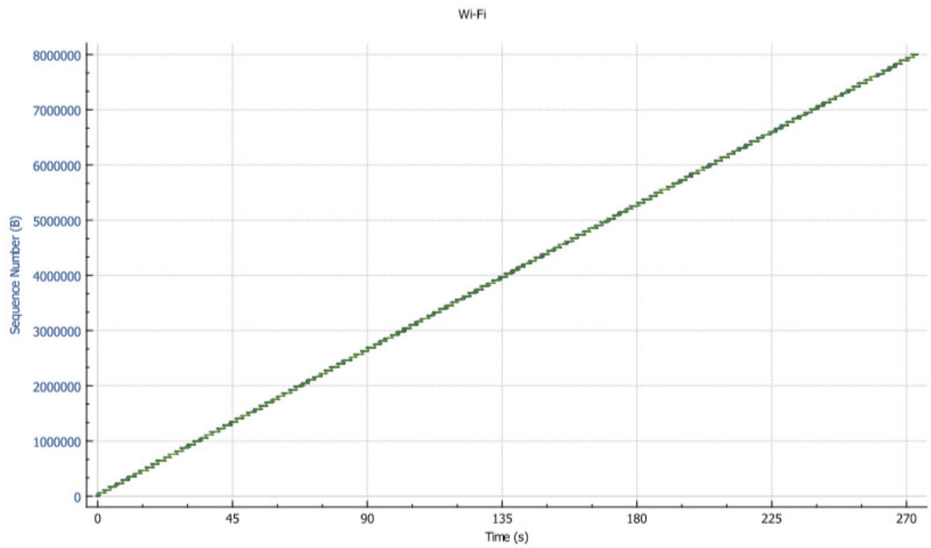


Figure 8. Sequence number versus time.

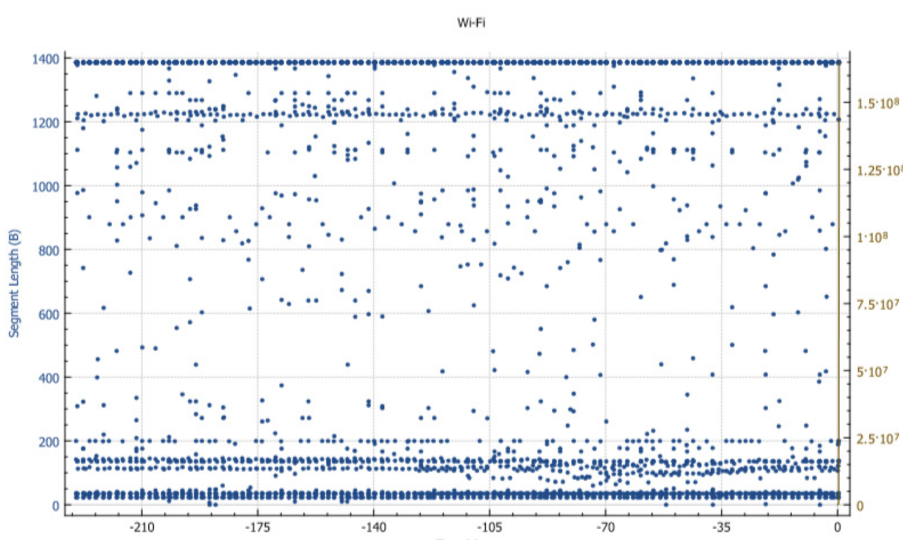
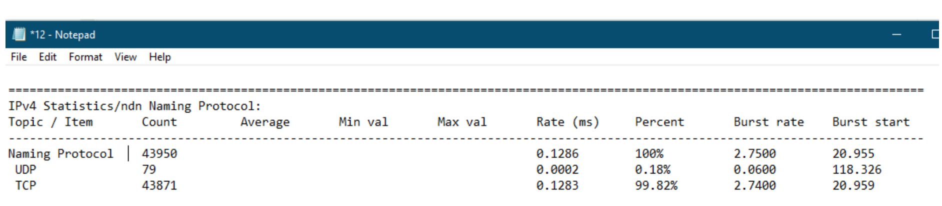


Figure 9. Average throughput and segment length versus time.



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IPv4 Statistics/ndn Naming Protocol:

Topic / Item	Count	Average	Min val	Max val	Rate (ms)	Percent	Burst rate	Burst start
Naming Protocol	43950				0.1286	100%	2.7500	20.955
UDP	79				0.0002	0.18%	0.0600	118.326
TCP	43871				0.1283	99.82%	2.7400	20.959

Figure 10. Proposed naming protocol.

content identification. It also labels the direction of bytes transmitted from each mobile producer so that data contents can be reassembled in the right direction and link of the rendezvous server.

The sequence number is recorded for 280 seconds. This utilizes up to 8,000,000 bytes of NDN contents during the whole simulation interval. During the simulation interval, transmission and reception of contents rise in a linear interval as shown in Figure 8.

5. Conclusion

Content-based network entities, like audio calls, video conferencing streaming, and social media platforms, have emerged prevalent and are the applications that create the most traffic on the internetwork. Hence, in the current IP paradigm, a packet of video application is retransmitted after transmission using its IP address location. This makes NDN paradigm resolve numerous IP paradigm issues especially during content transmission using accessible paths with minimum signaling and overhead costs, and by providing ease of retrieving object messages using its unique prefix name on the global Internet. The proposed scheme presents enhanced network efficiency and robustness. It also presents improved availability and scalability in term of information message and bandwidth demand after simulating the scheme in ndnSIM2.1, Wireshark packet analyzer is interfaced with to observe the input output transmission of contents, segment length, average throughput, and packet length. The study recommends implementing the scheme on a working test bed.

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