# Adaptive Interest Lifetime in Named Data Networking to Support Disaster Area

Raaid Alubady[1, 2], Suhaidi Hassan[1] and Adib Habbal[1]
*InterNetWorks Research Laboratory, School of Computing, Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia.*
*[2]Information Technology, University of Babylon, Babylon, Iraq.*
*raaid.alubady@internetworks.my*

***Abstract*—Pending Interest Table (PIT) in Named Data Network (NDN) maintains a track of forwarded Interest packets so that the returned Data packet can be sent to its subscriber(s). PIT size is a crucial parameter, which can have a huge impact on the number of both satisfied and timed out Interest packet, and consequently, on the number of packet delay in terms of PIT overflow. There are a lot of studies focusing on caching, applications, and security to make NDN getting perfect, while the management of PIT is still one of the primary concerns of high-speed forwarding. Thus, PIT manages mechanism is one of the most important design specifics that have not been studied in the context of NDN to a significant extent. NDN needs to define concise mechanisms to monitor traffic when multiple users contend for access to the same or different resources, which may lead the PIT is overflowing and as a result increasing the delay. In order that, the objective of this study is to provide an adaptive mechanism under network load, namely Smart Threshold Interest Lifetime (STIL) to adjust incoming Interest packet in the early phase of occurrence to propose possible response decisions to realize PIT overflow recovery. The ndnSIM network simulator was used to measure the STIL. The results demonstrate that the proposed mechanism outperforms the performance of standard NDN PIT with respect to average Interest lifetime, Interest satisfaction, Interest retransmission and Interest satisfaction delay. The significance of this study is to provide a fundamental direction of a new adaptive Interest lifetime mechanism in NDN router to decrease the delay, especially on the natural disaster in a city, which will be very much useful for emergency operation centers, emergency rescue teams, and citizens.**

***Index Terms*—Named Data Networking; Pending Interest Table; Natural Disaster; Interest Packet Lifetime.**

## I. INTRODUCTION

Named Data Network [1] architecture of the future is alternatives for the future of the Internet which concentrate on named data rather than named hosts (IP address) for the communication model [2], [3]. It has been gaining enormous attraction by the research community for the last eight years due to NDN has the potential to find a solution to several problems of the current Internet architecture, such as efficient resource utilization, in-network, security, naming, and routing [4]. However, it also has some critical issues, which need to be resolved, include, naming, routing, caching, forwarding, mobility, security, and applications [5]. Moreover, sharing of resources was a vital issue that forced significant difficulties with respect to correspondence among end hosts [6]. Among all these issues, routing and resource utilization are considered the most crucial component because it specifies that how to monitor and manage the data structure tables for incoming and outgoing packets.

NDN has two types packet: Data's packet and Interest packet. A subscriber sends an Interest packet to request the Data packet from the network. In addition, each NDN router includes three data structure: Content Store (CS), Forwarding Information Base (FIB) and Pending Interest Table (PIT). CS is a cache or a buffer set in NDN routers. The in-network caching system of NDN leverages on the next-generation of routers, which incorporate some caching memory for the goal of minimizing network bandwidth and latency demands, as well as the server occupancy. FIB is equivalent to the routing table in the conventional IP networks. It is used for forwarding the Interests to the publisher who is known to potentially hold the matching data. PIT is a cached table for Interest packet. Every Interest packet that requests content is forwarded to connect a node. The second role of the PIT is to prevent that multiple incoming Interest packets generate multiple packet forwarding When Interests for the same content are received, only the first one is forwarded; the others will be only pushed in PIT and wait for the Data packet back [1], [4], [7].

Hence, the PIT is used to maintain the state of each active flow. PIT grows with subscribers sending their Interest packets and shrinks when Data's packets are received at the in-network NDN router [8]. Since the access speeds required for such a structure, and the possibilities offered by the current memory technologies are limited in size, the PIT size might represent a bottleneck. The issue may be massive by an immense utilization of long Interest packet lifetimes, which may further enhance the volume of simultaneous entries in the PIT. This table can overflow with consequent service disruption. Whereat the PIT is overflowing; subscribers' requests will be discarded from the NDN router, and based on this; subscribers will experience an increasing retransmitting rate that causes many issues such as memory consumption as well as Interest retrieval delay and as a result lead to a complete collapse of the entire network [9]. Therefore, the management of PIT design is challenging due to its requirements, i.e., per-packet updates, look up speed and keep track of the currently unsatisfied Interest packets.

The studies in [10], [11], [12] and [13] proposed adaptive Interest lifetime techniques to adjust the Interest lifetime and regulate the Interest packet rate at the NDN. However, these works do not evaluate the number of unnecessary retransmission due to too short Interest packet lifetimes, adapt Interest packet lifetimes as a function of the subscriber node(s) not under the network load and as a result increases the delay as well as decrease the PIT utilization. In order that, the adaptation of an incoming Interest packet lifetime based on the current PIT condition was made by designing a Smart Threshold Interest Lifetime (STIL) mechanism to avoid overstaying of PIT entries during heavy network load and enhance PIT utilization.

The scope of this study focused on the disaster area. It is a local or a region, heavily damaged by either natural or technological. One of the important things that make disaster areas affected on the communication between the populations since the disaster area is the disruption of the normal functioning of a system or community, which causes a strong impact on people, structures and environment, and goes beyond the local capacity of response [14]. Flooding is a simple example of the natural disasters, which is caused when water submerges or overflows the land via heavy raining or tsunami. In this case, NDN routers between citizens and emergency stations may receive a heavy request from citizens to advise them of the location, situation or even the way of safety. On the other case, emergency stations need to guide the emergency rescue teams over this area, which may lead to sending and receive the message among them exponentially. However, these cases can increase the demand delay of PIT, especially when it is overflowing if we assume in the worst case, there is not an immediate response. Hence, the STIL will be quite useful for emergency stations, emergency rescue teams, and citizens through decrease the retrieval delay that is accompanying to transmit requests (see Figure 1).

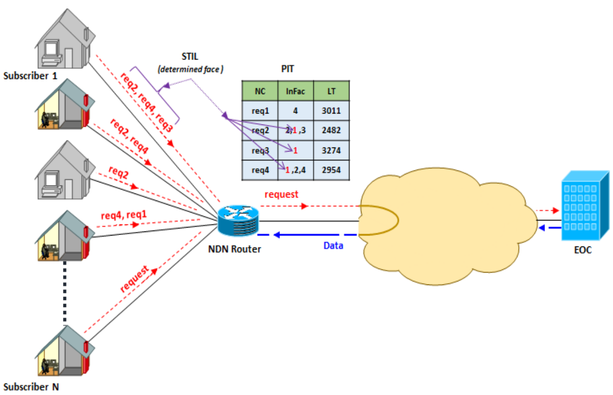


Figure 1: Interest Packet Workflow in NDN

In particular, design of Smart Threshold Interest Lifetime (STIL) mechanism in Section II. In the next section, flooding disaster area scenario based on STIL. Section III outlines the simulation setup as well as evaluation metrics. Section IV presents the performance analysis, results and discussions. Finally, the conclusion is presented in Section V.

## II. Smart Threshold Interest lifetime Model

Depending on the PIT status, PIT entry is associated with a timeout that is based on the estimation of an Interest packet lifetime [15]. The Interest packet lifetime parameter is selected by subscribers not under a network controller itself (i.e., based on the available NDN rules). Hence, PIT size may become more complicated by a huge usage of a long Interest packet lifetime that will increase the number of entries in the PIT [9]. The renewal theory [16] behind the STIL mechanism addresses issues of both Interest packet lifetime and PIT size.

In addition, the update procedure depends on the incoming Interest packets, which implies that every time packets arrive at the PIT, an update is required. The former issue can be resolved by assigning a specific parameter, while the latter is settled by an estimation using renewal theory and storing the entry based on the value of Interest packet lifetime and face behavior. An adaptive mechanism for the Interest packet lifetime is beneficial in NDN router scenario to control how quickly retransmission can be performed in case of PIT overflow.

Therefore, the main goal of this study is to develop a Smart Threshold Interest Lifetime mechanism (STIL) in Named Data Network for enhancing the management operations of PIT. This mechanism was proposed to manage the Interest packet lifetime at content PIT in NDN router that adjusts the Interest packet lifetimes as a function of the network load. Thus, NDN router grants less lifetime values for incoming Interest packets to prevent the PIT entries stay a long time during heavy network load and the PIT is full.

The STIL mechanism indicates that the Interest packet stores in the PIT for a short time when the PIT become overflow [17]. STIL has two options for adaptation Interest packet lifetime: the first option is to change incoming Interest packet lifetime based on given face received maximum number of Interest packet and recorded in the *'In-face list field'*, whereas the second option that is to change incoming Interest packet lifetime based on all entries in the PIT. Hence, the probability for changing Interest lifetime function according to STIL is:

$$T_{th} = \begin{cases} T_{th}(f_{\max}) = \dfrac{\sum_{i \in w} \rho_{\tau i}}{w} & if\ (f_{\max} > 0) \\ T_{th}(PIT) = \dfrac{\sum_{i \in PIT_{size}} \rho_{\tau i}}{PIT_{size}} & Otherwise \end{cases} \quad (1)$$

where $T_{th}$ is denoted as a threshold of an average lifetime that represents an entry lifetime in given face $T_{th}(f_{max})$ or all entries in the PIT; $T_{th}(PIT)$. The $T_{th}(f_{max})$ is the face that has received a maximum number of Interest packet and ($w$) is the total number of entries belong to given face $T_{th}(f_{max})$. Whereas the $PIT_{size}$ is the total number of entries belong to PIT. The ($\rho_\tau$) is the incoming Interest packet lifetime.

During overflow, the value of lifetime of an incoming Interest packet is updated based on Equation (2) as follows:

$$\rho_\tau = \min(T_{th}, \rho_\tau) \quad (2)$$

This can be helpful by granting shorter lifetime values in case of high traffic loads and the PIT becomes full. Hence, by applying Equations (1) and (2), it motivates the entry to keep alive for the shortest acceptable period before the expiration of entry lifetime. STIL is presented in Algorithm 1.

## III. Flooding disaster Area Scenario based on STIL

Communications capacity and tools are the lifeline of any major emergency response effort [18] such as flooding in the city which is caused by heavy raining or tsunami (see Figure 2). Whereas the quality of information, has made access to decision-makers, it is crucial in enabling responders to make timely decisions to save lives and alleviate human suffering. The Internet emergence and various technical approaches to connecting one user to many others have created many opportunities to get a much more efficient and timely response. Whenever possible, response organizations to take advantage of Internet connections have enabled local service providers because they are the most readily available and most cost-effective. During disaster strikes, communications links are essential in order to answer critical questions about the number of people who were injured or died, where the injured are located and the extent of the necessary medical assistance. Quite simply, in disaster and emergency situations, communication can save lives [19]. However, the emergency response delay [20] is one of the major issues that can disable responders to make timely, informed decisions. The main cause of that, the citizens and emergency teams or emergency operation center sends and receives a huge data among them. Thus, maybe a lot of the data packet will drop because of the PIT overflows in intermediate nodes (NDN routers) when many request Interests send to the same place and increased escalating crisis.

Algorithm 1: STIL Treatment

| STIL Algorithm |
|---|

Input:
*entry lifetime*
$f_{max}$ ← function returns whether there is a face has the maximum number of Interest or not.
Main process:
*if the PIT does not overflow then*
*Normal NDN processing*
*break*
*end_if*
*else // PIT does overflow*
*Check if there is any face has received the highest number of Interest packet arrival ($f_{max}$ > 0); And the Interest belong to this face ($\rho_\tau \in f_{max}$) then*
*for all entities belong the face has received the highest number of Interest packet into PIT do*
*Lifetime threshold is calculated based on:*

$$T_{th}(f_{\max}) = \frac{\sum i \in |w \, \rho_{\tau i}}{w}$$

*end_for*
*Go to step **
*end_if*
*else // The number of Interest packet received is the same for all faces Or the incoming Interest not belong to this face*
*for all entities belong in PIT do*
*Lifetime threshold is calculated based on:*

$$T_{th}(PIT) = \frac{\sum i \in PIT_{size} \, \rho_{\tau i}}{PIT_{size}}$$

*end_for*
*end_else*

**: Update the entry lifetime based on minimum between the Lifetime threshold and incoming entry lifetime based on:*

$$\rho_\tau = \min(T_{th}, \rho_\tau)$$

*End*

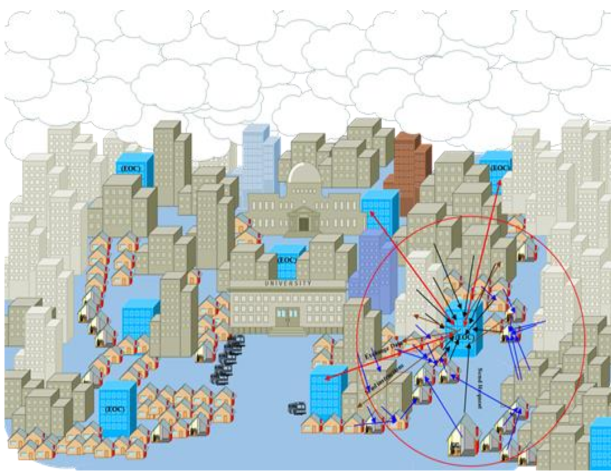

Figure 2: City under Flooding Disaster

NDN features are solved this concept since the subscribers may find the information of close NDN router in case its request before. However, because we are still using the current technology (storage capacity is limited) to store content in CS, PIT, and FIB, which can affect in the case of not an immediate or puny response. Since PIT is considered the most crucial component in NDN router because it keeps track of Interests packet forwarded upstream toward a content publisher (sources) so that returned Data packet can be sent downstream to its subscribers (requester). Thus, it needs a flexible mechanism to manage PIT in order to decide how the request to store when the PIT is full. Subsequently, it's increased the delay and as a result decrease the utilization of PIT.

## IV. PERFORMANCE ANALYSIS

The simulation environment is illustrated in Figure 1, modified version of a Rocketfuel-mapped AT&T topology was chosen [21]. Rocketfuel-mapped topology nodes are separated into three types: subscribers (296), NDN routers (108), and publishers (221) nodes (see Figure 3).

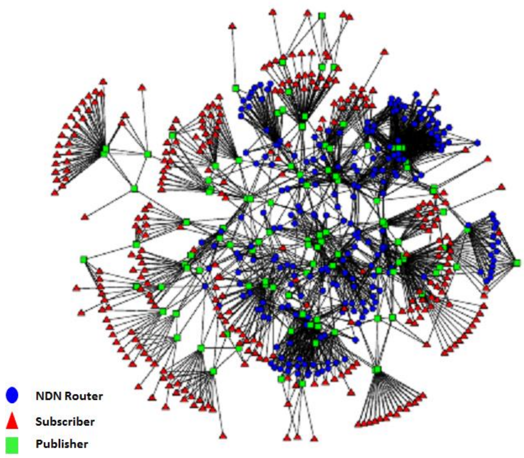


Figure 3: Simulation Environment - Rouketfuel Topology [21]

The experiment outcome for each simulation scenario compares the NDN PIT *("Notice that the NDN PIT" in this thesis refers to the standard PIT in NDN router without any additional enhancement")* simulation results with the STIL.

Table 1
Design Range for the Simulation Parameters

| Parameter | Description |
|---|---|
| Simulation Environment | ndnSIM [22] |
| Simulation Topology | Rocketfuel-mapped [21] |
| Forward Strategy | Flooding Strategy [23] |
| Interest Rate | 1000-10000 Interest/second |
| Content Store | 10000 Data packer |
| PIT Size | 1000 Interest packet |
| Interest lifetime | 80ms [24] |

### *A. Average Interest Lifetime Comparison*

Average Interest lifetime refers to a time period unsatisfied Interests remind in PIT. Figure 4 represents the average Interest lifetime of STIL and NDN PIT over different subscriber Interest packet rates. The vertical an x-axis represents the different Interest packet rate per second, while the horizontal a y-axis represents the average Interest lifetime. The figure shows that the STIL maintains the Interest lifetime at a minimum as short as possible since the PIT has overflowed. STIL adapts the lifetime of incoming Interest packets when the PIT overflows as the average Interest packet lifetime of (0.051671 seconds) to (0.046381 seconds) with the increase of the Interest packet rate from 1000 to 10000 Interest packet per second, respectively when the as compared to (0.055943 second) to (0.062397 second) with the increase of the Interest packet rate from 1000 to 10000 Interest packet per second, respectively, for NDN PIT. It was also observed that the PIT length was decreased by approximately (21%) as compared against the results obtained using NDN PIT.

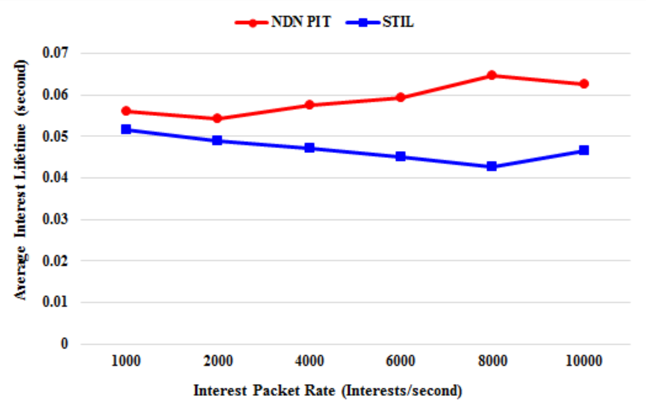


Figure 4: Average Interest Lifetime vs Interest rate for STIL and NDN PIT

### B. *Interest Retransmission Rate Comparison*

Interest Retransmission Rate is perceived by the subscriber that measures the percentage of Interest retransmission among the entire outgoing Interest packets when it is reissued because of timeouts [25]. Figure 5 shows the Interest retransmission rate of STIL and NDN PIT over different subscriber Interest packet rates. The vertical an x-axis represents the different Interest packet rate per second, while the horizontal a y-axis represents the Interest retransmission rate. Subscribers resent Interest packets that have been damaged and lost. Meanwhile, Interest packet retransmission after a time-out is necessary in order to recover losses, even though the Data packet may just be delayed at the bottleneck and/or the Interest packet is dropped when the PIT capacity is not sufficient. Thus, according to the results obtained, STIL and NDN PIT share the same trend with the Interest packet retransmission linearly increasing with the increase as the number of Interest packet rate provided by the subscriber. It can be seen for the PITCM; the Interest retransmission is increased as Interest packet rate increases, which are achieved between (12.39.98%) to (22.76%) with Interest packet rate from 1000 to 10000 Interest/second. On the other hand, NDN PIT obtained the similar behavior as a result since the Interest packet rate increases. The Interest retransmission also increases incremental, which is achieved between (19.94%) to (26.20%) with an Interest packet rate from 1000 to 10000 Interest/second. The graph below illustrates that when STIL is applied, the drop packets are minimal, and the retransmission required is at the minimum, thus saving the Interest packet retransmission costs. Hence, the STIL mechanism presented the best results as compared with DPEL and NDN PIT.

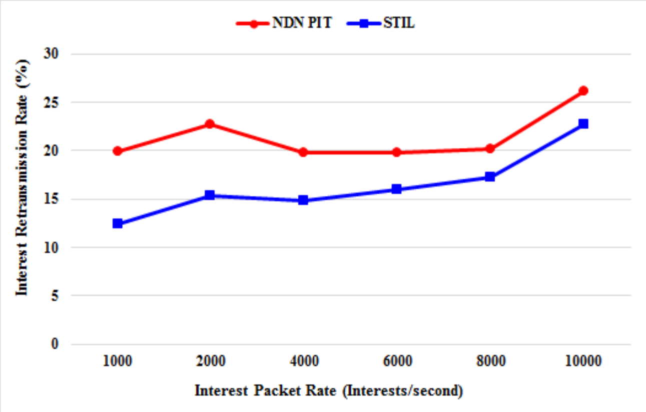


Figure 5: Interest Retransmission Rate vs Interest rate for STIL and NDN PIT

### C. *Interest Satisfaction Rate Comparison*

Interest Satisfaction Rate refers to the percentage of satisfied Interests per NDN router in the network [10]. Figure 6 depicts the performance comparison of PITCM and NDN PIT in terms of Interest satisfaction rate. In the given figure, an x-axis presents Interest packet rate per second. Whereas a y-axis represents the Interest satisfaction rate. According to the results obtained, PITCM and NDN PIT may share the same line since they decrease the Interest satisfaction as the Interest packet rate increases. However, as saw in the given figure, with the increase of the Interest packet rate from 1000 to 10000, the Interest satisfaction rate has recorded a decrease from (52.44%) to (33.87%) in NDN PIT. In PITCM, this reduction is from (53.58%) to (47.01%). Hence, PITCM guarantees that with high Interest packet rate scenarios (10000 Interest packet rates per second), the Interest satisfaction rate can be maximized, which is (38.80%), as compared to NDN PIT. Hence, this guarantees that with a low and a high Interest packet rate, the Interest packet satisfaction rate is dramatically maximized as compared to NDN PIT.

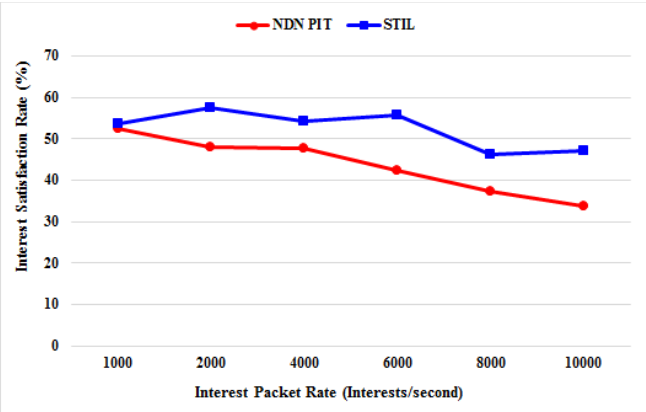


Figure 6: Interest Satisfaction Rate vs Interest rate for STIL and NDN PIT

### D. *Interest Satisfaction Delay Comparison*

Satisfaction Delay Comparison refers to the time interval between the first Interest generated by the subscriber for the specified content and the Data packet received in satisfying [26]. One of the main concepts of NDN is that the packets must be forwarded with minimum delay by making the NDN routers have the ability to store the copy from every Data packet passing over these nodes. However, PIT overflow is sometime another reason to introduce delay when Data packet return and did not find any matching with the PIT entries due to the entry is dropped or replaced. Therefore, it is important in order to measure the delay when designing a new approach.

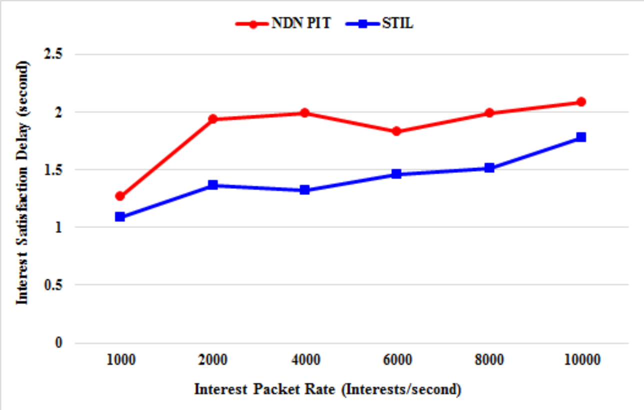


Figure 7: Interest Satisfaction Delay vs Interest rate for STIL and NDN PIT

Figure 7 summarizes the Interest satisfaction delay of PITCM and NDN PIT over ten different Interest packet rates. The Interest satisfaction rate refers to the time interval between the first Interest generated by the subscriber for the specified content and the Data packet received in satisfying. Although NDN PIT and PITCM showed a gradual rise in Interest satisfaction delay as the Interest packet rate rises, NDN PIT seemed to have Interest satisfaction delay higher than PITCM. In brief, PITCM achieves between (15.67%) and (17.33%) lower than NDN PIT Interest satisfaction delay as the Interest packet rate is 1000 to 10000 Interest/second, respectively.

## V. Conclusion

Despite the numerous advantages of NDN router tables, several hardware challenges are faced, which include the PIT in terms of Interest packets processing in the NDN router. In addition, PIT size that requires to be monitored for incoming Interest packet and to be managed the entries inside the PIT. The problem becomes more critical when the impending PIT overflows during the heavy load of Interest packets. Therefore, the main objective of this paper was to design and implement the Smart Threshold Interest Lifetime (STIL) mechanism to address this problem. Moreover, the effectiveness of proactive adjustment Interest lifetime in increasing network utilization, and limiting the Interest packet delay. The simulation results found, STIL outperforms the NDN PIT in Interest satisfaction, Interest retransmission, average Interest lifetime and Interest satisfaction delay. Since the NDN PIT gave a poor performance in case of increasing number of Interest rate. The On the other hand, the significance of this study by presenting a framework for flooding disaster scenario in cities and shown the ability of STIL to increase network utilization and decrease the packet delay in a vast city. Thus, it will be very much useful for the emergency operation center, emergency rescue teams, and citizens. As a result, the proposed mechanism can be considered as a general solution for PIT management in term of adaptive incoming Interest lifetime that may increase the probability of the PIT become overflow in NDN router in a broader sense in flooding disaster scenario.

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