Dynamic Interest Retransmission Interval Method for Congestion Control in NLSR

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Abstract. Named data link state routing (NLSR) protocol is widely used in current NDN architecture. Due to the limited bandwidth resources of NDN, in the large-scale network running NLSR, when routing information is frequently updated, resulting in a sudden increase in interactive information and the Interest storm is formed. It will cause congestion of protocol information flow and affect network quality and performance index. NLSR does not take corresponding control measures for its Interest traffic and transmission frequency. Therefore, we propose a method to solve this Interest storm: the exponential regression algorithm is used to dynamically adjust the retransmission interval of Sync Interest and the timeout retransmission Interest quantity detection method is provided to add the flow control. The simulation results show that the congestion control method can adjust the sending quantity and retransmission interval of Interest well according to the network traffic.

1. Introduction

The Named data Link State Routing protocol (NLSR) uses Named data Networking (NDN) Interest and (signed) Data to exchange Routing information [1-2]. The protocol stipulates that the router should refresh the Link State Advertisement (LSA) generated by itself every LSARefreshTime interval. However, a large-scale network running the NLSR requires a large number of Interest/Data to exchange various routing information: the Hello packet is used to establish connections between neighbor routers, the Sync packet is used to keep linkstate databases consistent between neighbor routers, and the LSA packet is used to synchronize routing updates [3].

In particular, when network update frequently in a short term, a large number of Sync Interest will be generated. After the Sync Interest/Data are interacted, the network will generate LSA Interest corresponding to the Sync Interest Carrying updated routing information. NLSR also faces the problem of congestion caused by flooding of Interest, but no further improvement measures have been taken to address the problem.

From the perspective of transmission mechanism optimization, an improved method is proposed: 1) The exponential regression algorithm is used to dynamically adjust the retransmission interval of Sync Interest in the period when the protocol information flow has congested the network; 2) The timeout retransmission Interest quantity detection method is provided to add provided to add the flow control of all Interest. Finally, we conducts network simulation experiments based on the ndnSIM platform, verify that the proposed method can effectively improve network performance.
2. Communication mechanism in NLSR protocol

NLSR protocol communication mechanism consists of two main interrelated parts, the Hello protocol and the Link-State Database synchronization mechanism. The Hello protocol detects neighbors and maintains adjacency relationships, and the synchronization algorithm ensures that all routers in the unified domain always have a consistent Link-State Database.

2.1. Hello protocol

NLSR uses the Hello protocol to periodically send Hello Interest to determine the state of the connection to the neighbor routers.

The Hello protocol detects a change in neighbor state. Through the Hello Interest/Data interaction, the router can detect the failure of the neighbor and determine the state of the neighbor. If the Router does not receive a Hello Data from its neighbor for a sufficiently long period of time (determined by the parameter RouterDeadInterval), the connection is broken and the faulty node is bypassed to find other linkable routes [4].

2.2. Link-State Database synchronization mechanism

The Link-State Database (LSDB) synchronization enables each synchronization group to achieve and maintain a consistent state of the shared dataset, with the synchronization protocol (ChronoSync) used to coordinate differences among the shared datasets. Basic synchronization process is the interaction of Sync Interest/Data. All routers in the scope of the network periodically multicast Sync Interest containing synchronized states to their neighbor routers to check for consistency.

ChronoSync uses an encrypted digest data structure called state digest to name the Sync packet [5]. The state digest is the concatenation of the hash value of the latest data name of each producer according to the naming rules, which is used as a condensed description of the state of the dataset. An example of synchronization process of ChronoSync is shown in the figure 1. In figure 1(a), routers A, B, and C are in a stable stage (including state digest 1, 2 and 3) and have the same Sync Interest pending in the network. When A generates new Sync Data (including state digest 4), both B and C start to update their ChronoSync module to add state digest 4. In figure 1(b), After repeating the above steps many times, the routers enter a new stable state. Each router sends out a same Sync Interest (carrying state digest n) containing the updated state digest.

2.3. LSA update mechanism

There are two forms of synchronous update in link-state routing protocol: 1) When routers establish communication preparation, it needs to obtain the routing advertisement name prefix; 2) When LSA is added or refreshed, the routers advertise the name prefixes to ensure that the databases are updated synchronously, that is, the LSA traffic update mechanism.

While the synchronization process is complete, the NLSR provides Sync Logic Handler to act as an interface between the synchronization protocol and the LSDB.
Sync Logic Handler receives the update notification sent to NLSR. NLSR retrieves the LSA's name in the local LSDB and determine if the LSA needs to be updated. If so, the updated neighbor is requested to send the LSA to update the local LSA name set. The neighbor that receives the request Interest generates the corresponding Data containing the LSA update information and returns along the original path. After the Data received locally is verified, the updated version of LSA is obtained and stored in LSDB. LSDB update between adjacent routers is completed, reaching a stable state. Repeat the above process until all routers receive the updated LSA. The LSA synchronization update process is shown in Figure 2.

Figure 1. Synchronization process of ChronoSync.

Figure 2. LSA synchronization update process.

3. Congestion control method based on Interest retransmission interval
The update flow of the Interest is composed of two parts: the Interest sent normally and timeout retransmission Interest [6]. Normally transmitted Interest should be adjusted appropriately according to the load condition of the network to control the number sent per unit time; Timeout retransmission Interest should not be repeatedly and frequently retransmitted due to network congestion.
3.1. Sync Interest retransmission interval control
In the existing ChronoSync module, when the Sync Interest failed to be acquired due to timeout, it was simply re-created and sent again, without considering the need to dynamically adjust the Sync Interest retransmission for different conditions. By setting the timeout retransmission interval of Sync Interest through the exponential regression algorithm. The following algorithm is used for calculation:

\[
\begin{align*}
R(1) &= R_{\text{min}} \\
R(i + 1) &= \text{Min}(KR(i), R_{\text{max}}), \text{if } i \geq 1
\end{align*}
\]  

(1)

Among them: \( K, R_{\text{max}} \) and \( R_{\text{min}} \) are constants, \( R(i) \) represents the RexInterval value of the \( i \)-th Sync Interest retransmission. The \( \text{Min} \) function is the minimum value function, taking the smaller value of the two. \( \text{max} \) is set to RouterDeadInterval, \( R_{\text{min}} \) is set to SyncInterestLifetime, and \( K \) is adjusted to network conditions. This algorithm is used to calculate the Sync Interest retransmission interval.

3.2. Timeout retransmission Interest flow control
Section 3.1 is just a control method for the Sync Interest of repeated retransmissions. The timeout retransmission Interest quantity detection method is provided to add the flow control of all Interest.

The following variables are defined: \( N(t) \) is the number of timeout retransmission Interest at time \( t \); \( h(n) \) is the maximum threshold value of the number of timeout retransmission Interest allowed; \( l(n) \) is the minimum threshold value of the number of timeout retransmission Interest allowed; \( Q(t) \) is the time slot when Interest are continuously sent to the neighbor router at time \( t \); A is the coefficient of time slot increase or decrease; \( T \) is the minimum interval for time slot change; \( Q_{\text{min}} \) is the minimum time slot; \( Q_{\text{max}} \) is the maximum time slot. The following relationship indicates the change of time slot in the Interest flow control:

\[
Q(t + T) = \begin{cases} 
\text{Min}(Q(t)\lambda, Q_{\text{max}}), & \text{if } N(t + T) > h(n) \\
Q(t), & \text{if } l(n) \leq N(t + T) \leq h(n) \\
\text{Min}(Q(t)/\lambda, Q_{\text{max}}), & \text{if } N(t + T) < l(n)
\end{cases}
\]

(2)

The flow control mechanism determines the congestion state of the network. It indirectly adjusts the continuous sending slot of Interest in the process of adjusting the retransmission quantity of Interest. This method can effectively balance the number of timeout retransmission Interest between routers and control them within a certain range.

4. Simulation
We use the NS-3 based ndnSIM simulation platform to simulate the performance of NLSR protocol. The configuration file \( \text{nslr.conf} \) for the NLSR contains a number of parameters that can be set for link-state and stored statically. The test environment simulates the process of nodes establishing connection and running NLSR protocol to update routing information synchronously. As shown in the figure 3, the network topology simulates the Producer, Consumer and intermediate routers, and all nodes are started within 400s. Interest congestion occurs at 120s. It indirectly adjusts the sending rate and generated quantity of Interest carrying routing update information in the network by controlling the LSA item update rate at the Producer, so as to simulate the congestion state.
As shown in figure 4: during the routing update process, the number of Interest carrying the update information is directly proportional to the update rate. When the protocol information flow cause congestion, the timeout retransmission mechanism lead the router to generate more Interest. The horizontal coordinate is the routing update rate, and the vertical coordinate is the number of Sync Interest sent by the router under test in the simulation time. The ICC in the legend is described as the NLSR using the Interest congestion control method. After the congestion control of Sync Interest, the sending quantity can be stable within a certain range to maintain the network load balance.

![Network test topology](image)

**Figure 3.** Network test topology.

As shown in figure 5: packet delivery rate represents the ratio between the number of Interest received by destination nodes and the number of source nodes. This index can reflect the reliability of data transmission. It can be seen that with the increase of the routing update rate, the network protocol flow becomes more busy, and the packet delivery rate of the network decreases. The NLSR with ICC method has improved the packet reception rate, and remained the packet delivery rate relatively stable.

![Impact of ICC on the number of sent Sync Interest](image)

**Figure 4.** Impact of ICC on the number of sent Sync Interest.
5. Conclusion

We studied the Interest storm caused by frequent routing updates in the short-term during the operation of NLSR protocols. By analyzing the communication mechanism between routers, we propose improvement measures from the perspective of optimizing the resource information transmission mechanism: providing Interest flow control method implicitly detects and controls the number of timeout retransmission Interest, and using the exponential backoff algorithm to dynamically adjust the retransmission interval when the Sync Interest are repeatedly retransmitted to aggravate congestion. Through experimental simulations, it can be known from the data curve diagram that the NLSR with ICC method can adjust the number of Interest sent according to network traffic, and better implement a mechanism for measuring and controlling Interest traffic, which can reduce the possibility of Interest storms. In this way, the transmission of protocol information flow can be more effectively controlled, and the network can achieve load balance.

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