A Segmentation-Based Data Contention Resolution Method For Optical Named Data Networking

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***Abstract*—Named data networking (NDN) is a typical solution for next-generation internet systems, and its applications and architectures are now widely demonstrated in both wired and wireless communications. Optical named data networking (ONDN) is an NDN architectural scheme proposed in recent years for use on an optical transmission network, which is an important initiative of NDN for the future development of high-speed broadband internet. Although the idea of ONDN data interaction based on I/R/D protocols has been proposed, the network nodes cannot adopt packet aggregation or division of prioritized packets. In this paper, based on I/R/D communication protocols, fully considering the characteristics of the NDN network architecture on an optical transmission network, we give a feasible method of performing aggregation or division of prioritized packets, analyze the performance of a network that adopts more than one strategy, and prove the feasibility of the method proposed in this paper and the method's enhancement of network performance through a simulation platform to provide certain experimental ideas for the future of the NDN architecture on the optical transmission network.**

***Keywords*—Named data networking;data contention; packet loss; packet aggregation**

I. Introduction And Contributions

With the increasing demands of users regarding internet speed, an information-centric information transmission model has been proposed. Information-centric networking (ICN) [1] realizes information-centric communication by decoupling the content from the storage address with the name of the data content. Named data networking(NDN) [2] regards the content itself as the dominant entity in the network and adopts a content-based architecture to replace the current host-based network architecture; it has thus become a representative network architecture for forward-looking research. In NDN, the data information entity is given a unique name, and the data requester(subscriber) encapsulates the name of the desired data content in an Interest packet and sends it to the NDN network, while the owner of the desired data content (publisher) encapsulates the information required by the subscriber into a Data packet, which is returned along the original path of the Interest packet to the subscriber, completing an information interaction.

For NDN architectures in the optical transport layer, current research is still insufficient. There are some problems and without workaround. First of all, there is no packet aggregation process in the I/R/D protocol. Secondly, different content requesters in the network have different content priority packet quality of service requirements.

Network users may prioritize the content of requests or use packet aggregation techniques and that there is currently no specific capability in the ONDN network to handle prioritized or aggregated packets. The above issues can be categorized into three scenarios:

Scenario 1: The network prioritizes packets only and does not use a packet aggregation policy. Scenario 2: The network uses only packet aggregation policies and does not prioritize packets. Scenario 3: The network prioritizes packets and uses packet aggregation.

In view of this we propose a priority packet aggregation contention resolution method for the I/R/D protocol. The method describes the forwarding process of ONDN network nodes for aggregated packets and describes the method of addressing aggregated packet contention under the I/R/D protocol, based on which it presents prioritized packet processing and forwarding using the aggregation strategy and finally obtains the packet loss rate of the network under the adoption of different strategies to be analyzed. We build the first simulation platform to analyze the performance regarding the Data packet loss rate and the feasibility of the proposed method is proved. The results obtained provide an important reference for the future design of NDN communication protocols based on optical transmission structures.

II. Related Work And ONDN Principles

A. Related Work

At present, the research field of NDN network mainly focuses on interest forwarding [3], internet of things [4], interest flooding attack [5], cache replacement [6], information security [7], etc., and the optical transport layer based on wavelength division multiplexing (WDM) technology has become one of the most important candidates for the development and demand of ultra-high-speed broadband Internet in the future, especially in the architecture of backbone network and metro core layer. WDM optical transport networks play a dominant role. Therefore, ICN/NDN architecture in WDM optical transmission physical layer is the development trend of NDN network system.

Optical named data networking (ONDN) [8-9] constructs an NDN network on a WDM network [10], and the I/R /D (Interest/Response/Data) communication model is proposed to establish the NDN communication protocol on WDM.

B. ONDN Principles And Contention

The three main types of packets used in the I/R/D protocol [11] are Interest packets, Response packets and Data packets. The subscriber encapsulates the unique name corresponding to the desired data content in the Interest packets and sends them to the ONDN. When the publisher responds to the Interest packets, it encapsulates the data content name and other information into the Response packets. After the Response packets enter the ONDN network, the wavelength resources are reserved at each node in the path of the Interest packets, and after waiting for a certain bias time (offset time), the publisher encapsulates the content information into the Data packets along the way and returns it to the subscriber. When the Interest packets and Response packets pass through the ONDN nodes, they are converted into electrical signals for processing, and the Data packets maintain an all-optical signal for transmission throughout.

Packet aggregation in ONDN is different from NDN packet aggregation [12] and WDM packet aggregation. Due to the complete optical transmission of Data packets and the absence of content storage tables in the intermediate routing nodes in ONDN, the NDN and WDM packet aggregation methods cannot be directly applied in ONDN.

Packets is handled at different network structure. In ONDN, Interest packets processing and forwarding are converted into electrical signals and processed in the NDN layer, whereas Response packets processing and forwarding consider processing in the NDN layer but also take into account the WDM characteristics of reserving resources for Data packets, and Data packets aggregation focus on processing in the WDM network. In NDN, both Interest packets and Data packets are processed in the NDN layer. There are no Response packets in the NDN.

The timing of aggregation is also different. In ONDN, Interest packets enter the aggregation cycle at every node, Response packets do not enter the aggregation cycle, and Data packets only enter the aggregation cycle at the beginning and then no longer enter the aggregation cycle to maintain all-optical signal transmission. In the aggregation of Interest packets and Data packets, the main aggregation methods have different focuses, but all of them take priority as the auxiliary judgment condition. In NDN, Interest packets and Data packets enter the aggregation cycle at every node. There are no Response packets in the NDN.

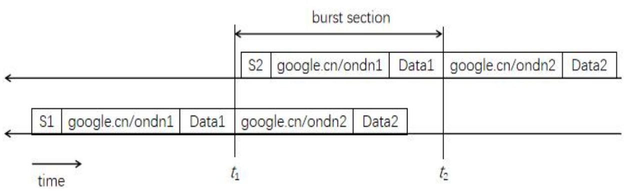

Fig. 1. Contention diagram

Data packets are transmitted in the network in an all-optical form without being converted to electrical signals, and there may exist two Data packets that need to be forwarded out of an interface at the same time, in which case a contention occurs. The contention diagram is shown in Fig. 1, where subscriber S2's Data packet arrives while subscriber S1's Data packet has not yet completed transmission. It should be noted that the contention occurs in this situation regardless of whether the packet aggregation strategy is used.

III. DATA CONTENTION RESOLUTION METHOD

If the network can handle the process of scenario 3, it can also handle scenario 1 and scenario 2. The proposed method will query the table by using the find-table method and will return the corresponding subscript if the query content exists and -1 if it does not exist.

When Interest packets arrive at an ONDN node, it aggregates the Interest packets with the same request content name within a time period to decide whether to send a Data packet or forward the Interest packet based on the content in CS, and modifies the PIT and FIB. The process is shown at below:

Algorithm 1: Interest packet handling forwarding method

```
Input: Interest packet (Msg), Content Store (CS), Pending Interest Table (PIT), Forwarding Information Base (FIB), End-of-cycle flag (flag)
Output: Returns false if the packet is deleted, true otherwise
while !flag then
    if The same request content exists in the Interest packet and has the same priority then
        Aggregate Interest packets
        delete Msg
        return true
    else
        Accept the Interest packet
    end if
end while
CSIndex←findTable(Msg,CS)
if CSIndex>=0 then
    Generate a Data packet based on the CS entries
    if flag then
    Generate a Response packet based on the Data packet and forward it; forward the Data packet after the offset time
    return true
    else
        if The same subscriber Data packet exists and has the same priority then
            Aggregate Data packets
        else
            Accept Data packet
        end if
        After the end of the cycle, generate a Response packet for the Data packet and forward it; forward the Data packet after the offset time
        return true
    end if
else
    PITIndex←findTable(Msg,PIT)
    if PITIndex>0 then
        If the entry does not contain interface information or requester information, add information to the entry
    else
        Generate new pending interest table entries to join the PIT
    end if
    Generate new pending interest table entries to join the FIB
    return true
end if
return false
```

When a Response packet arrives at an ONDN node, it updates the FIB and queries the PIT, and discards the packet if there is no corresponding entry in PIT. The node reserves resource for the destination interface and modify the wavelength reservation table (WRT).If the reservation fails, the packet will be discarded. The process is shown at below:

Algorithm 2: Response packet handling forwarding method

```
Input: Response packet (Msg), Content Store (CS), Pending Interest Table (PIT), Forwarding Information Base (FIB), Wavelength Reservation Table (WRT), Start time, End time
Output: Returns false if the packet is deleted, true otherwise
FIBIndex<-findTable(Msg,FIB)
if FIBIndex<0 then
    Add Response packet arrival information to the FIB
end if
PITIndex←findTable(Msg,PIT)
if PITIndex<0 then
    delete Msg
    return false
else
    if There are available resources for the reservation period then
        Write the reservation information to the WRT; forward Msg
        Delete the PIT [PITIndex] information
        return true
    else
        flag←false
        for i<-0 to WRT.size() do
            if WRT[i].Priority<Msg.Priority&&startTime<WRT[i].endTime&&endTime>WRT[i].endTime then
                flag←true
                break
            end if
        end for
        if flag then
            delete WRT[i]
            Add information such as the reservation time of the Response packet to the WRT
            return true
        else
            delete Msg
            Send a status packet to the Response packet arrival information
            return false
        end if
    end if
end if
```

Data packet processing and forwarding is described as follows:

Algorithm 3: Data packet handling forwarding method

```
Input: Data packet (Msg), Wavelength Reservation Table (WRT)
Output: Returns true if the packet is forwarded, false otherwise
if the packet resource is not reserved in the WRT then
    delete Msg
    return false
else
    if there are resources available for the interface then
        forward Msg
        return true
    else
        if There are no low-priority packets then
            delete Msg
            return false
        else
            Consume this resource for forwarding; low-priority packets are segmented and partially discarded
            return true
        end if
    end if
end if
```

IV. SIMULATION

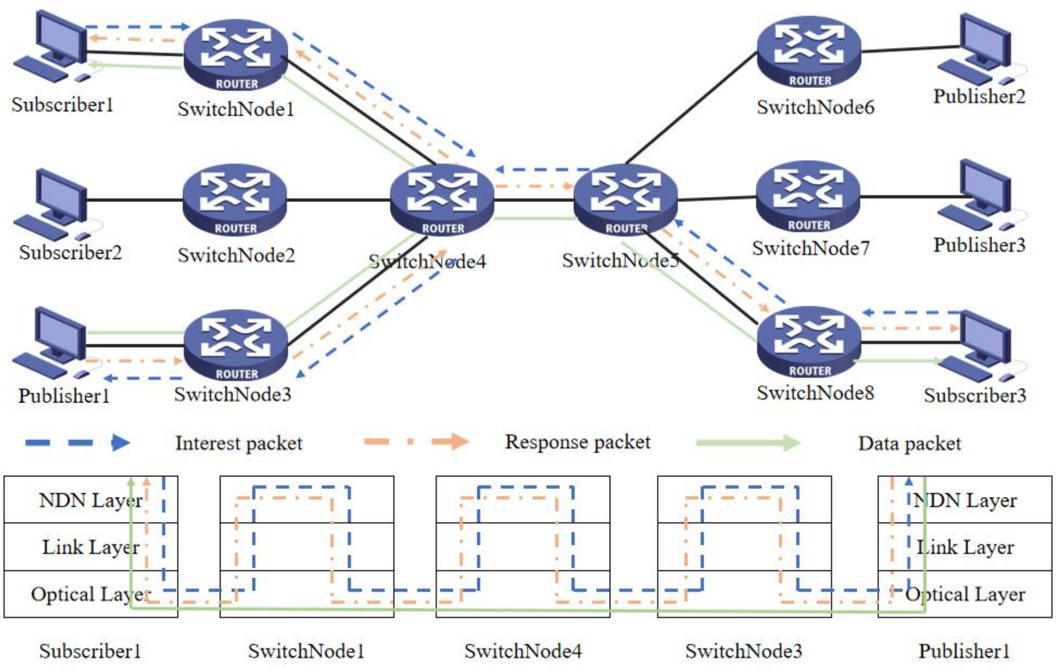

Fig. 2. Network topology diagram and packet transmission process

A. EXPERIMENTAL CONFIGURATION

OMNeT++ is used to build the ONDN simulation platform. Subscriber, publisher and network nodes are set up in the network. The topology is shown in Fig. 2. The subscriber sends Interest packets to the ONDN network at a rate of λ packets per second, Interest packets can be satisfied by at least one publisher, and Interest packet sending obeys a Poisson distribution. The bandwidth of a single-wavelength channel is 2.5 GB/s, and one fiber can carry channels of multiple wavelengths through multiplexing. Each subscriber sends a total of 10,000 Interest packets. The Data packet size is 5 MB. If priority is divided into high and low, the proportion of high-priority packets is 20%.

The process of sending Interest packets, Response packets and Data packets in the network with the I/R/D protocol is shown in Fig. 2. Subscriber1 sends an Interest packet through network nodes to Publisher1, and Interest packet undergoes photoelectric conversion in network nodes. Publisher1 responds to the Interest packet by sending a Response packet back to Subscriber1 along the original route, and the Response packet also undergoes photoelectric conversion in the network node. Publisher1 sends the Response packet along the original path back to Subscriber1. The Response packet in the network node also undergoes photoelectric conversion. The Data packet travels back to Subscriber1.

B. Experimental results and analysis

In the simulation experiments, the network packet loss rate is compared and analyzed for three strategies at different Interest packets request rates. The three strategies are as follows. Strategy 0: No packet aggregation strategy is used, and packets are not prioritized. Strategy 1: A packet aggregation strategy is adopted, and packets are prioritized. Strategy 2: A packet aggregation strategy without prioritization is adopted. The simulation experiments prove that the proposed method is feasible.

The packet loss rates for Data packets of high priority in networks with different policies at different Interest packet application rates are shown in Fig. 3, from which it can be seen that the packet loss rate increases linearly with the application rate. Strategy 0 has the highest packet loss rate. Strategy 2 adopts a packet aggregation strategy on the basis of Strategy 0, so its packet loss rate is lower than that of Strategy 0. Strategy 1 replaces low-priority packets with high-priority packets in case of contention on the basis of Strategy 2, which can further reduce the loss rate of high-priority packets.

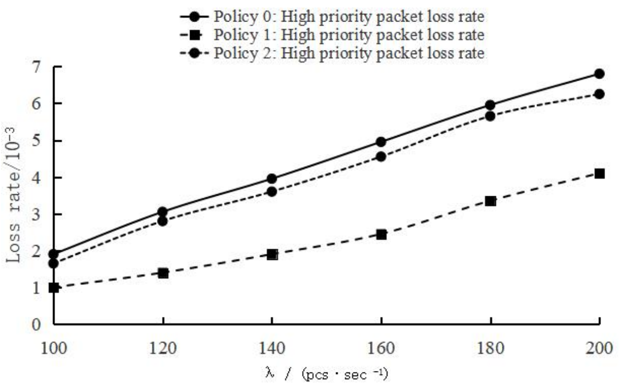

Fig. 3. The packet loss rates of Data packets with high priority in networks with different policies under different Interest packets application rates

The packet loss rates of low-priority Data packets for different strategies and different Interest packets request rates are shown in Fig. 4. It can be seen that the packet loss rate of low-priority packets with strategy 1, which discards low-priority packets in case of contention, is significantly higher. Strategy 2 adopts the packet aggregation policy, which reduces the packet loss rate of low-priority packets. With the packet aggregation strategy, both the high-priority and low-priority packet loss rates of Strategy 2 are reduced compared with those of Strategy 0.

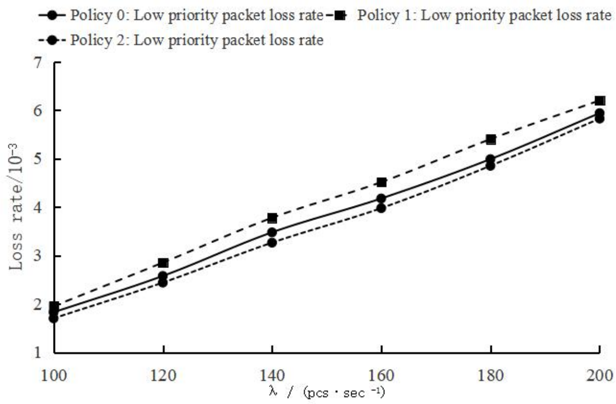

Fig. 4. The packet loss rates of low-priority Data packets in networks with different policies under different Interest packet application rates

The average packet loss rates of Data packets with different policies and different Interest packets request rates is shown in Fig. 5. Since both Strategy 1 and Strategy 2 use packet aggregation, the average packet loss rates of all packets are lower than those of Strategy 0. Strategy 1 discards the conflicting parts of low-priority packets when there is a contention, and Strategy 2 discards the conflicting parts, so the two are similar overall because the simulation adopts a Poisson distribution; this causes a certain degree of fluctuation, as the Interest packets are sent more centrally, so the packet loss rate will fluctuate.

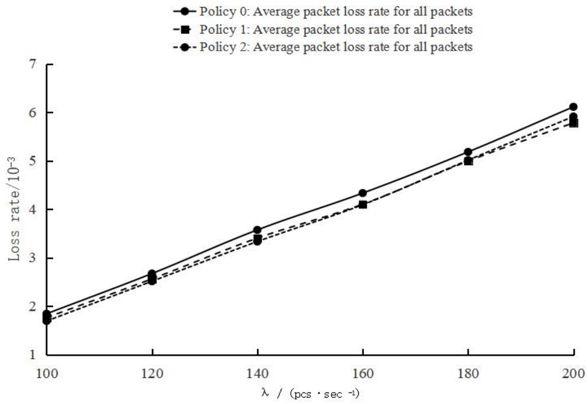

Fig. 5. The average packet loss rates of Data packets in networks with different policies under different Interest packets application rates

The packet loss rates of Data packets under Strategy 1 with different Interest packets application rates are shown in Fig. 6, and the network packet loss rate shows an upward trend with increasing rate. It can be seen that under the strategy of packet aggregation and prioritization, the packet loss rate of high-priority packets can be effectively reduced, while the packet loss rate of low-priority packets increases. The increase in the high-priority packet loss rate is lower than the average packet loss rate and the low-priority packet loss rate, which proves that this method can effectively reduce the high-priority packet loss rate of the network and ensure the quality of network service for the requested content Data in the network.

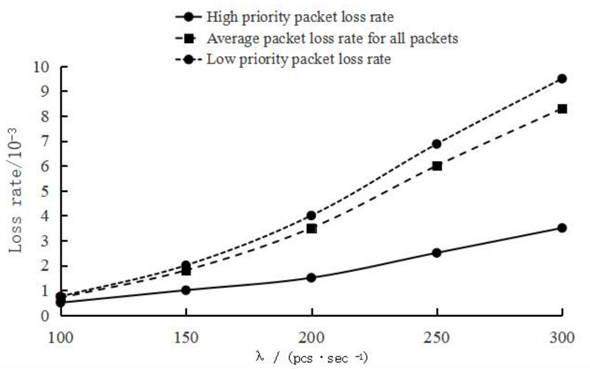

Fig. 6. The packet loss rates of Data packets under different Interest packets application rates in the network with Strategy 1

V. CONCLUSION

In this paper, the performance of ONDN based on the I/R/D protocol using different strategies is studied to address issues with network nodes forwarding packets using packet aggregation or prioritization. The characteristics of the ONDN network are incorporated to obtain a comprehensive method. This method can apply more than one strategy for packets, and its feasibility is demonstrated through experimental simulation to study the performance of different strategies for ONDN networks. According to the simulation results, the following conclusions are drawn: first, the method proposed in this paper can handle the loaded and sent aggregated packets, and the adoption of packet aggregation can reduce the packet loss rate in the network; second, the method proposed in this paper can effectively handle the prioritized packets, and based on the adoption of the packet aggregation strategy, the division of packets into priority levels can reduce the loss rate of high-priority packets and ensure the quality of network service for high-priority packets.

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