

# Safety Monitoring Scheme of Gas Pipeline Network Based on Multi-homing Technology

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**Abstract.** The gas pipeline network is one of the key infrastructures for the energy supply of modern cities, and its safety is crucial to the life and development of urban residents. The traditional gas pipeline network monitoring method mainly relies on regular inspection and manual intervention, which has problems such as monitoring blind zone, slow response time and low monitoring accuracy. To address these issues, we introduce multi-homing technology into our gas network safety monitoring solution. First of all, we deploy multiple sensor nodes in key locations such as gas pipelines, valves, and connection points in the gas pipeline network, and each sensor node is equipped with multiple communication interfaces, which can be connected to different networks at the same time. We classify the collected data according to QoS traffic and assign links according to service level, and use multi-homing technology to perform multiple transmission and multiple reception, optimizing data transmission time and reliability.

**Keywords:** gas pipeline network monitoring; multi-homing; Qos; transfer of information; data collection.

## 1. Introduction

The gas pipeline network is one of the key infrastructures for the energy supply of modern cities[1], and its safety is crucial to the life and development of urban residents. The safety monitoring of the gas pipeline network is a key link to ensure the normal operation of the pipeline network system and prevent potential risks. The traditional gas pipeline network monitoring method mainly relies on regular inspection and manual intervention, which has problems such as monitoring blind zone, slow response time and low monitoring accuracy. In order to solve these problems, a gas pipeline network safety monitoring scheme based on multi-homing technology came into being.

For the gas pipeline network safety monitoring scheme, the research background lies in the potential safety hazards and insufficient monitoring methods of the current gas pipeline network system[2]. The conventional gas pipeline monitoring relies on manual inspections, has blind spots, and lacks comprehensive accuracy. Emergency response times are slow, making it challenging to prevent accidents. Therefore, multi-homing tech-based monitoring fills these gaps, enhancing accuracy, response speed, and accident prevention.

With the development of network communication[3], multi-homed technology came into being, which uses a variety of sensors and monitoring equipment to improve the coverage and accuracy of monitoring systems through data fusion and comprehensive analysis. With the rapid development of science and technology[4], intelligent monitoring has become an important development direction of urban construction. As an important energy supply infrastructure of the city[5], the introduction of multi-host technology safety monitoring scheme can not only improve the intelligence level of the pipe network, but also integrate with other city management systems to achieve comprehensive management of smart cities.

We implement multi-homing tech in the gas pipeline network safety monitoring. We transmit sensor data via multiple network links, categorize data by traffic, assign service levels based on importance, prioritize important data, and use more reliable links for transmission.

## 2. System Design

In this paper, we introduce multi-homed technology to the gas pipeline network safety monitoring scheme to realize multiple transmission and multi-receipt of data, multi-homed technology has the characteristics of distributed deployment, diversified sensors, real-time monitoring and feedback, remote monitoring and control, as well as intelligent analysis and decision support. These features make multi-homed technology more efficient, comprehensive, and reliable in gas network safety monitoring and control.

### 2.1 Design Ideas

Traditional solutions often use simple data transmission and processing methods, which cannot transmit and synthesize large amounts of data. This can lead to monitoring systems being unable to accurately judge and predict the status and anomalies of the gas pipeline network, as well as to provide timely alarms and early warnings in the shortest possible time. We apply multi-homing technology to the gas pipeline network safety monitoring scheme to realize multiple transmission, multiple receipt, batch transmission of data, and optimize data transmission time and reliability[6].

We need to send, receive and process the collected data through multiple networks, but because it is difficult to achieve multiple data sending and receiving at the same time and there is no guarantee that there will be no errors in the information transmission process, we need to prioritize the transmission of important data in the collected data and ensure its transmission quality, which requires traffic classification and link distribution technology[7].

### 2.2 System Model

Fig. 1 shows the overall framework of this solution, we first deploy multiple sensor nodes in the gas pipeline network, which are distributed in key locations such as gas pipelines, valves, and connection points. Sensor nodes can use pressure sensors, temperature sensors, gas concentration sensors, etc. to monitor the operating status and environmental parameters of the pipe network. Each sensor node has multiple communication interfaces and can be connected to different networks at the same time.

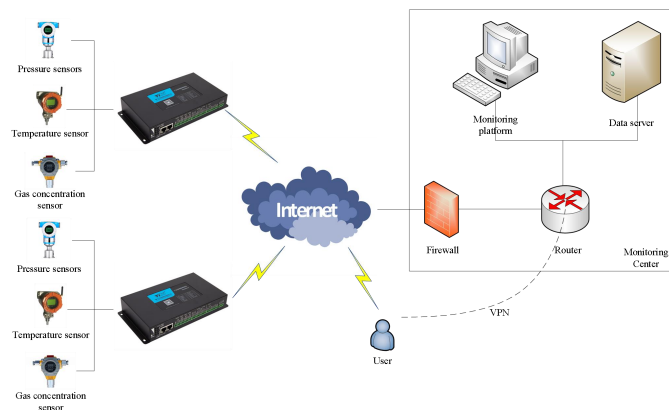


Fig. 1. Overall framework

Then the collected data is classified into traffic, and different network links are assigned according to the service level, for example, the pressure and temperature data in the gas pipeline network will be classified as important traffic that needs to be transmitted first, and the more stable network links will be allocated according to its service level.

Data collected by sensor nodes can be sent to multiple data centers or cloud platforms simultaneously through multiple communication interfaces[8]. On a data center or cloud platform, multiple receiving and processing nodes are established to receive and process data from sensor nodes[9].

### 3. Detailed Implementation

#### 3.1 Traffic Classification Deployment

The deployment process of traffic classification is the process of classifying and identifying traffic in a network according to certain rules and policies. The process is:

(1) Determine Classification Goals: First, you need to clarify the goals and requirements for traffic classification. Based on actual demand, determine the type of traffic to be classified.

(2) Design Classification Rules: Design rules for traffic classification based on the classification goal. Rules can be determined based on regular expressions, feature matching, IP address ranges, etc.

(3) Configure the Classification Policy: Configure the designed classification rules and policies to the corresponding devices, such as routers, firewalls, traffic monitoring devices, etc. Configuration can be implemented through the management interface, command line interface, or appliance script.

(4) Flow Monitoring and Acquisition: Start monitoring and collecting traffic data in your network. You can use a traffic monitoring tool or appliance to capture, analyze, and record network traffic data. These tools enable real-time analysis and statistics of traffic and provide relevant reports and charts.

#### 3.2 Traffic Classification Module

##### 3.2.1 Classifier Template

Classify traffic entering the DiffServ domain so that it is appropriately processed in the network. The main purpose of flow classification is to let other application systems or devices that process this packet know the category of the packet, and perform some pre-agreed processing of the packet according to this category.

Configuring flow classification can classify packets that meet certain rules into one category and distinguish user traffic, which is the premise and basis for implementing differentiated services. The rules of a flow classification belong to a parallel relationship, and as long as the matching rules do not conflict, they can be configured in the same flow classification. When used by users, it can be configured according to their needs.

If a flow classification has multiple matching rules, there are two logical relationships between the rules: And and Or:

(1) Or Logical: A packet belongs to this class as long as it matches any of the rules defined by an if-match clause under that flow class.

(2) And logic: When there are ACL rules in a flow class, the packet must match one of the ACL rules and all non-ACL rules to belong to that class; If there are no ACL rules in the flow classification, the packet must match all non-ACL rules to belong to the class.

##### 3.2.2 Behavior Template

Flow classification is done to provide services differently, and it must be associated with some kind of flow control or resource allocation action to make sense. Flow control or resource allocation actions are called flow actions. Fig. 2 shows the relationship between interfaces, Policy, Behavior, classifier, and ACL.

(1) Different interfaces can apply the same Policy template.

(2) One or more Classifier & Behavior pairs can be configured in a Policy template. Different Policy templates can apply the same Classifier & Behavior pair.

(3) One or more if-match statements can be configured in a Classifier template, and ACL rules can be referenced in if-match statements. Different Classifier templates can apply the same ACL rules. An ACL rule can be configured with one or more Rule statements.

(4) One or more Actions can be configured in a Behavior template.

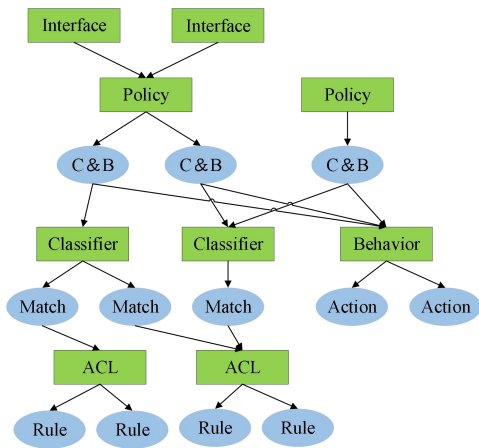


Fig. 2. Diagram of the different modules

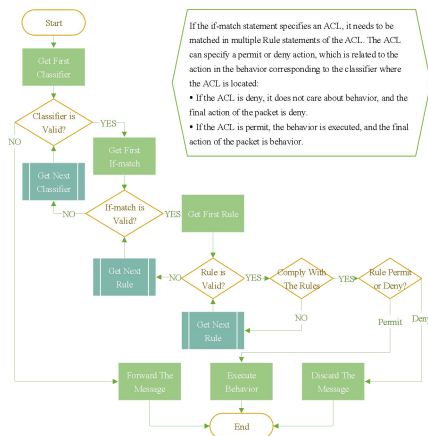


Fig. 3. Policy execution process

### 3.2.3 Policy Template

This is shown in Fig. 3, when a packet is received for complex stream classification, it is matched in the order in which the Classifier is configured in the policy template. If it hits, the match stops; If it is not hit, the following Classifier is matched; If the last Classifier is not hit, the packet is forwarded normally, similar to if no flow classification policy is applied.

Since one or more if-match statements are configured in the Classifier, the match is performed in the order in which the if-match statements are configured; If the if-match statement specifies an ACL or UCL, it is necessary to match in multiple Rule statements of the ACL or UCL: first find out whether the user has configured the ACL or UCL (because flow classification allows references to ACLs and UCLs that do not exist), and the first match stops further rule checking.

When the action in the Rule is Deny, if the behavior is mirrored or sampled, the behavior will be executed even for dropped packets.

The ACL can specify a permit or deny action, which is related to the action in the behavior corresponding to the classifier where the ACL is located:

(1) If the ACL is deny, it does not care about behavior, and the final action of the packet is deny.

(2) If the ACL is permit, the behavior is executed, and the final action of the packet is behavior.

### 3.3 Link Distribution Module

Traffic is divided into two types: internal traffic and external traffic, external traffic is easy to distribute, and internal traffic distribution is relatively difficult. Traffic distribution techniques can be divided into three types according to the granularity of distribution, namely, traffic distribution per packet, traffic distribution by different connections established, and traffic distribution by segment. Per-packet allocation applies to networks where the BGP protocol is applied; Per-connection assignment applies to NAT networks; Segment-by-segment allocation is useful when multiple connections need to be allocated at once. In a multi-home network with BGP protocol applied, traffic distribution can be performed by modifying route advertisements, but this distribution is not a real-time traffic balancing method, but the distribution scheme can only be updated at the same time as the advertisement. One way to combine NAT in multi-home networks that use NAT is through DNS. DNS returns the result of selecting links at the same time as the query, but this allocation mechanism can only be allocated each time the DNS is queried, so it cannot assign links to multiple connections connected to the same destination.[10]

The traffic distribution mechanism we propose uses a per-connection distribution approach. When the application establishes a connection on the link, it invokes the traffic distribution program to select a link for the connection and complete the traffic distribution before establishing the connection. The traffic distributor first checks whether the application enforces that multiple connections must be performed on the same link. This is because in the design of some applications, the default is that multiple connections must be established on the same link, and if the application contains multiple connections, this requirement must be performed on the same link, and the traffic distribution procedure selects the link on which the application has previously established a connection so that the application continues to establish connections on that link. If the application has no requirements, the traffic distributor proceeds to the next step.

Next, the traffic distribution program calculates a link-state reference value based on the link status, economic factors, existing connection status and other influencing factors of the link. Here we introduce the link-state reference value calculation formula.

We introduce the FLARE[11] formula to calculate fast traffic. The FLARE mechanism is a mechanism that specifically calculates the load traffic of each link in multipath transmission, which monitors the load status of each link in the multipath and calculates the reference value of each link state, and finally obtains the optimal link according to the link state reference value. The specific form of the FLARE formula is shown in (1).

$$p = \frac{\left( \left( \frac{\sigma}{\mu} \right)^2 + 1 \right)}{4 \cdot \varepsilon^2 \cdot [N(t)]} \tag{1}$$

where  $\sigma/\mu$  represents the variable that affects the link state, and  $N(t)$  represents the traffic on the link in t time. The link-state reference value P is calculated, and the larger the reference value, the better the current link state.

Based on this formula, we derive that the traffic distribution formula is:

$$p = \frac{\left( \left( \frac{\sigma}{\mu} \right)^2 + 1 \right)}{4 \cdot \varepsilon^2 \cdot E \cdot N} \tag{2}$$

where  $\sigma$  represents the bandwidth status of the link, with a bandwidth of 100Mb as the baseline, the parameter value  $\sigma$  is 1, and other bandwidth parameters are calculated according to this ratio.  $\mu$  represents the delay condition of the link, which is divided into 1 to 10 in a total of 10 levels, and level 1 is the lowest delay. It can be seen that the larger the bandwidth, the larger the  $\sigma$ , and the larger the link state reference value; The greater the link delay, the larger the  $\mu$  and the smaller the link-state reference. E represents the billing status of the link, which can be divided into 10 levels from 1 to 10, with level 1 being the cheapest condition. The larger E, the more expensive the link billing and the smaller the link state reference value. N represents the number of existing connections on the link, and the larger N, the smaller the link state reference value.

#### 4. Related Work

With the advantages of wide coverage, multi-dimensional correlation and large data volume of the Internet of Things, combined with the spatiotemporal data analysis and visualization functions of GIS, Zhang et al. designed a scientific underground gas pipeline network monitoring system, which can not only dynamically monitor the safety status of the underground gas pipeline network, but also assess and warn potential risks, which is helpful to further improve the safety of urban gas supply[12]. Yu et al. used GIS technology and pipeline network monitoring and early warning technology to realize the digital management of gas pipeline network, and built an information management and early warning system for urban gas pipeline network[13]. Du et al. proposed an analysis method for the importance of risk factors in gas pipeline network based on logistic regression, and used the ordered multi-classification logistic regression method to rank the risk factors according to the absolute value of the regression coefficient[14]. A. Kawabata et al propose a multihomed network design model called MHND to balance low latency and high availability when distributed processing applications use multiple processing servers[15].

#### Conclusion

We used a Qos strategy based on complex stream classification in this study, and in future studies, we will try to apply time-division multiplexing technology to data transmission, we divide time into several time slots, each time slot is used to transmit a data. Individual data are transmitted in their respective time slots in a predetermined order. Each data occupies a period of time in the corresponding time slot and is transmitted during that time period. In order to ensure that each data can be transmitted according to the time slot, the time-division multiplexing system needs to have a unified clock source to ensure that the clocks of each device are synchronized. This allows the sender and receiver to accurately identify each time slot and transmit and receive data according to the time slot.

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