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PREDICTION OF PEER-TO-PEER ROUTING REQUEST BASED ON LOW-POWER AND LOSSY NETWORKS BEHAVIOR ANALYTICS

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ABSTRACT

Techniques are provided to predict Peer-to-Peer (P2P) routing requests in Low-Power and Lossy Networks (LLNs). With this prediction, a P2P routing path may be prepared on demand and in advance.

DETAILED DESCRIPTION

Peer-to-Peer (P2P) routing is an important functionality for Low-Power and Lossy Networks (LLNs), especially for Distribution Automation (DA) scenarios.

As of today, there are several Institute of Electrical and Electronics Engineers (IEEE) Request for Comments (RFC) standards and papers describing enhancements to build P2P routing path in LLNs. There are also many papers describing LLN P2P routing technology. These mechanisms may be divided into two categories: (1) prepare P2P routing path before P2P request; and (2) prepare P2P routing path after P2P request.

However, a P2P routing request is somewhat random in LLNs. For example, in the DA scenario, the P2P routing request is generated along with grid events, while grid events occur randomly. Therefore, the P2P routing mechanisms have their own problems with meeting random P2P routing requests. For a P2P routing path prepared before the P2P request, most time the prepared P2P routing path may not be effective and may be resource wasting. For a P2P routing path prepared after the P2P request, since it takes time to build a P2P routing path, LLN nodes must wait until the P2P routing path is done. This reduces the efficiency of P2P routing.

As such, a solution to balance the "before" and "after" is provided herein. In particular, described is a mechanism to predict a P2P routing request in an LLN. With the prediction, a P2P routing path may be prepared on demand and in advance, which balances the "before" and "after."

To support network behavior analytics, data may be collected from the LLN. This data may include data relating to the P2P routing request (e.g., time, P2P source, P2P destination, duration, etc.), grid events (e.g., time, type, traffic pattern, etc.), logging on LLN nodes (e.g., time, content, etc.), and other data that can support LLN behavior analytics.

Behavior analytics may be applied to the collected data. A connection may be built among the data, and rules of prediction generated. Figure 1 below illustrates the overall system.

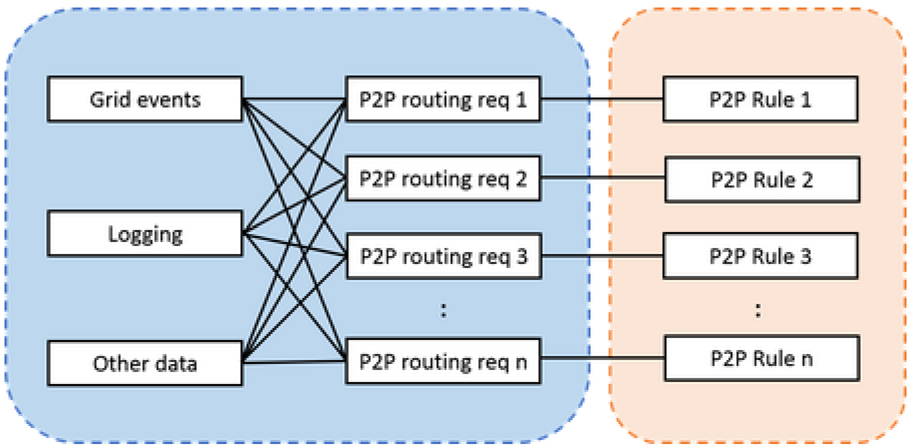

Figure 1

A typical example rule may be: [Input: (Event_1, Event2, ..., Event x), (Log_1, Log_2, …, Log_y), (Data_1, Data, 2, …, Data_z), Output: (P2P_src, P2P_dst, P2P_time)].

Classification may be applied to the generated rules to figure out P2P routing categories. A regular P2P routing request refers to a P2P routing request that happens regularly, such as a request that always happens at the same time every day between two LLN nodes. A random P2P routing request refers to a P2P routing request that always happens randomly, but with certain event/log/data patterns. This is illustrated in Figure 2 below.

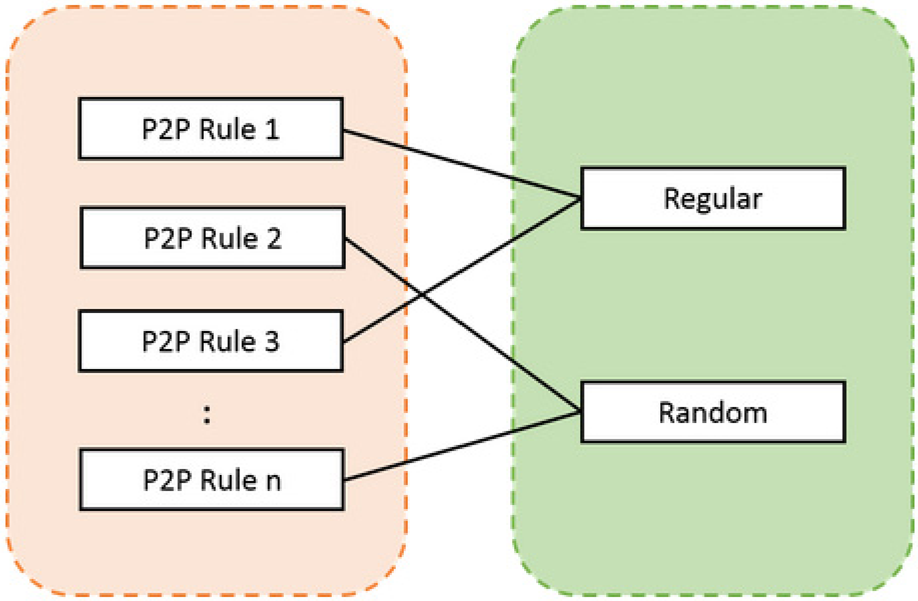

Figure 2

A logistic regression classifier is a popular algorithm to solve the 0-1 problem, and my help predict the routing categories. Input values $x = x_0, x_1, ..., x_n$ are combined linearly using weights or coefficient values to predict an output value y as in the following formula:

$$P(y=1|x;\theta) = g(\theta^T x) = \frac{1}{1+e^{-\theta^T x}}$$

where g(h) is a sigmoid function used at the core of the method, and p(y=1|x; θ) represents the probabilities of 1 with given inputs x.

An example multivariate hypothesis function is $h_\theta(x) = \theta^T x = \theta_0 + \theta_1 x_1 + ... + \theta_n x_n$. An example cost function formula is J(θ):

$$J(\theta) = -\frac{1}{m}[\sum_{i=1}^{m}(y^{(i)} \log h_\theta(x^{(i)}) + (1-y^{(i)})\log(1-h_\theta(x^{(i)}))]$$

When the prediction model is trained, the probability may be maximized by minimizing the loss function using optimization techniques such as gradient descent.

P2P routing request predictions may take place differently according to the rule category.

For P2P routing requests that happen regularly, it is easy to take action accordingly. For example, as illustrated in Figure 3 below, node H needs to send traffic to node K at

3:00PM every day. According to this rule, nodes H and K can build a P2P routing path before 3:00PM every day (the build method may be any existing P2P routing method).

Figure 3

For P2P routing requests that happen randomly, event/log/data analytics may happen on LLN nodes, so as to predict whether the P2P routing request will be generated.

For example, as illustrated in Figure 4 below, node H needs to send traffic to node K anytime every day.

Figure 4

The following steps may take place on nodes H and K. First, events/logs/data are collected on nodes H and K. Second, events/logs/data are fed to a prediction module. Third, the prediction module analyzes events/logs/data. Fourth, the prediction module finds a piece of matching prediction rule. Fifth, the rule shows that the P2P routing request may occur soon between nodes H and K. Sixth, the prediction module may trigger building of a P2P routing path immediately (the build method can be any existing P2P routing method). Seventh, the P2P routing path may be instantiated between nodes H and K. Eighth, P2P routing occurs between nodes H and K.

In summary, techniques are provided to predict P2P routing requests in LLNs. With this prediction, a P2P routing path may be prepared on demand and in advance.