Fuzzy Logic Based Adaptive Update Mechanism for Routing Information Protocol

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Abstract

Routing Information Protocol is one of the oldest interior gateway routing protocols which is still being used in a lot of small networks. An important feature of this protocol is that periodic updates are sent by the routers to their neighbors. The updates are sent irrespective of any changes in the routing table. Such unnecessary update messages result in wastage of a lot of bandwidth especially in small networks. One proposed option for improvement is to change periodic updates to triggered ones, which allows routers to send updates only in case of change in routing table. Such triggered mechanism can result in flooding of the network with update messages when there are a lot of frequent changes or any link or router is malfunctioning. We propose Fuzzy Logic based adaptive update mechanism to determine the method of sending update messages in order to optimize bandwidth consumption and to reduce the risk of flooding of the network. We use a number of related parameters to intelligently decide if triggered or periodic updates are suitable for the present conditions of the network. The proposed mechanism is adaptive as it dynamically re-evaluates the criteria for every event.

1 Introduction

Routing Information Protocol (RIP) [1] is one of the oldest routing protocols at the intra domain level. RIP uses distance vector routing algorithm to calculate best routes in local network. Routers communicate with each other as they send their routing tables to the directly connected neighbors. The cost is considered in hop counts with the limit of 15, 16 hops are considered unreachable. On receiving the message from neighbor, the entries that are missing or which have less cost than the existing entries are added to the routing table after incrementing each entry by one.

RIP requires sending routing information to the directly connected routers periodically, after every 30 secs. The continuous update mechanism actually consumes a lot of bandwidth even when there is no change in the routing tables [2]. There is also an option of triggered updates which enables routers to send routing information when they detect any changes, in addition to regular updates. The additional triggered mechanism can increase the bandwidth consumption by the routing packets. RIP introduces hold down timer of 1 to 5 seconds which is set after sending the triggered update to reduce the number of triggered updates [1].

Gani et al. [2] proposed changing the periodic routing update mechanism to a triggered one. The authors proposed that the routers only send routing message when they detect any changes. Their results showed that bandwidth consumption is lower in this case as it works very well when there are normal network conditions.

We argue that even though the triggered update mechanism works well in normal network scenario by resulting in reduction of bandwidth consumption by routing messages, there could be a problem with such mechanism. The triggered updates are sent when there is a change in link cost, link is down or a router is down. In case of malfunctioning of a link or router, the triggered updates can flood the network and may result in network breakdown. For example, if a router is malfunctioning or link is coming up and down continuously due to some problem, then triggered updates will be sent for every event, which can be many in few seconds. Such triggered updates will be sent to the neighbor routers and changes will propagate further, so the whole network can be flooded by these unnecessary messages.

We propose that triggered updates are good when there are few changes observed. The moment the number of changes are frequent the triggered updates need to be stopped for every event and periodic updates are sent to make sure that the changes are sustained. We propose Fuzzy Logic based Adaptive Update Mechanism (FLAUM) for RIP that considers following four parameters of importance for deciding if periodic or triggered update messages should be sent:

- Time Elapsed from the Last Update: We use this parameter as an indicator to call for the proposed update mechanism. If the time from last update is low only then router needs to pursue the mechanism any further.
- Frequency of Changes: This parameter is introduced to handle the situations when the router itself is malfunctioning or have some configuration error.
- Changes in Particular Parameter of Routing Table: If a particular parameter of the routing table is changing too frequently that may indicate problems with particular link or router so our mechanism uses this parameter to handle such cases.
- Number of Sustained Changes: We keep track of the sustained changes in order to accommodate the situation when complete or big part of the network is going under change due to reconfiguration or update.

The rest of the paper is organized in the following manner: Section 2 discusses some basic principles of Fuzzy Logic and emphasize why it is suitable for this problem. Section 3 discusses our proposed approach FLAUM for optimally finding the method to send update messages by routers using RIP. Section 4 concludes the paper and provides future work options.

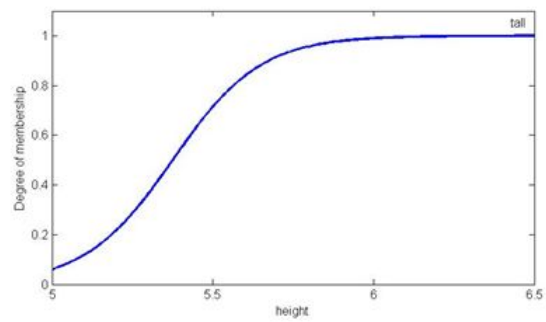

Figure 1: Example of Fuzzy Membership Function

2 Fuzzy Logic

Fuzzy Logic is the field of computational intelligence that provides an easy to use and adapt systematic mechanism to deal with uncertainty in the knowledge base. Fuzzy Set Theory [4] is a Soft Computing paradigm that provides graded membership functions to accommodate imprecision in data values. Graded membership is represented with the help of different membership functions, e.g. triangular, Gaussian, sigmoidal etc. definitions. For instance, the concept of "tall" can be represented as a sigmoidal membership function, as shown in Figure 1.

Fuzzy Logic works with Fuzzy Sets [5] to perform approximate reasoning. Fuzzy Sets are unlike traditional sets as the graded membership allows an element to be partially part of the set in contrast to traditional sets which require sharp boundaries that an element is either a member or not a member of a set, but can not be both.

Linguistic variables are employed to encapsulate expert knowledge and later use to make decisions. Such variables use linguistic terms to define universe of discourse of the Fuzzy Sets. These terms allow to use a not very clearly defined mode of reasoning which resembles human reasoning process. Inference is performed on simple conditional statements in the form of IF-THEN rules.

The overall working of the approximate reasoning method in Fuzzy Logic can be summarized as finding the compatibility with each IF-THEN rule of the given input and then combining the compatibilities to find the output, which can be a set or a single defuzzified value.

2.1 Why Use Fuzzy Logic

The issue of RIP update mechanism calls for a solution that is intelligent, transparent, and adaptable. It should be intelligent so that it can work with imprecise parameter values and loosely defined relationships. It should be transparent so that its performance can be analyzed and tuned. It needs to be adaptable as the results can be based on initial hints provided by domain experts. Hence, Fuzzy Logic is the most suitable candidate for resolving the issue.

It is important to point out that we propose the use of Fuzzy Logic for resolving this issue also due to the inherent characteristics of Fuzzy Logic which are: a) low computational overhead as compared to other intelligent paradigms like Neural Networks, Genetic Algorithms etc., b) support of linguistic variables which provides easy to use and easy to understand means for configuring networks, and c) support of range definition of parameters which makes the system flexible and customizable.

3 FLAUM

After providing a brief overview of Fuzzy Logic, we discuss our proposed approach in this section.

3.1 Overview

Fuzzy Logic based adaptive update mechanism provides intelligent and dynamic approach for routers using RIP to decide that under the present network circumstances, updates should be sent periodically or triggered. For easy understanding we use the term *update message* for all types of routing messages sent by any router to its neighbors. The complete mechanism is discussed in step wise fashion here:

- Step 0 **Initialization**: At the start, router sends the update message to all its neighbors and keeps the record of the time message is sent. Router puts itself in complete stable stage (instability =0), which makes it send triggered updates only.

- Step 1 **Routing Table Change Event**: If a change in routing table entry occurs then router checks the time elapsed from sending the last update message. If the time is less than X (Network Administrator (NA) defined customized parameter, default = 30sec) then router increments instability parameter by I (the value of I can be chosen by NA, default = 0.1). In case the time is more than X then decrement instability by I. The possible three cases are:

- Case 1: Instability is low, send message immediately.

- Case 2: Instability is high, send message periodically.

- Case 3: Instability value changes from high to low or vice versa, go to Step 2.

- Step 2 **Check Stability**: The router checks the Fuzzy Logic rule base (described in detail in the next section). If the result is stable network state, make instability zero and send update message immediately. On the other hand, if network state is unstable, make instability as 1 and only send periodic updates.

3.2 FLAUM Working

The Fuzzy Logic based approach uses three parameters as input and there is one output, as discussed below:

- Input 1: Frequency of Change (FC): If changes are very frequent then it may be the router itself which is unstable. If FC is high then output will always be unstable.

- Input 2: Change in Particular Parameter (CPP): If any particular routing table entry is changing very frequently then the related router or link may be malfunctioning. If CPP is high then output will always be unstable.

- Input 3: Overall Sustained Changes (OSC): If the network is being reconfigured, updated or changed then there will be a lot of changes but most of them will be sustained. In such cases, FLAUM needs to stay in stable state as there are no errors or malfunctioning involved.

- Output: Network State (NS): The only output is NS to determine that the network state is stable or unstable.

The first input parameter FC is introduced to make sure that the router itself does not have any errors in configuration. Router keeps a record of how many changes have occurred in recent past (say last 5 minutes) and a range is defined for this parameter from low to high.

The second input parameter CPP takes care of the malfunctioning network entity, router or link. With each routing table entry the number of changes in that particular entry in recent past is also recorded. If the routing table entry has high CPP then it may be an indication of the related link or router having problems. The range of CPP is defined from low to high.

The third input parameter OSC is introduced to record the fraction of routing table entries in recent past which have sustained the change. For example, if in last five minutes there were total four changes and two of them are of the same routing table entry and other two are of other entries then 75% of the changes are considered sustained. The range of this parameter is also from low to high. OSC is not related to number of changes but is relevant to the changes that are sustained to cater for scenarios when network is being reconfigured.

The only output parameter NS shows that the network and its entities are stable or unstable at that time.

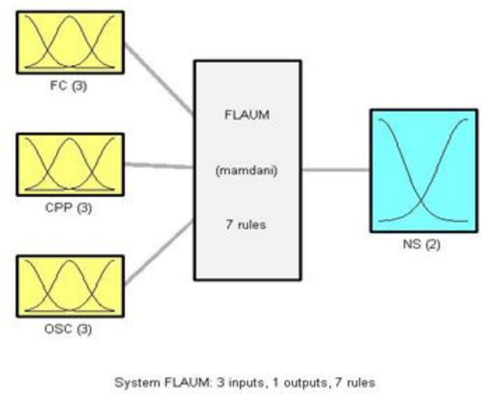

Figure 2: Schematic of the Fuzzy Inference System

3.3 Design

The Fuzzy Inference System has three input variables, FC, OSC, and CPP. There is one output variable NS. All variables are normalized to the range [0,1]. The universe of discourse for the three inputs is divided into three linguistic terms: {low, medium, high}, described by Gaussian membership functions. The universe of discourse for the output is divided into two Gaussian fuzzy linguistic terms {unstable, stable}. Fuzzy rules for deciding the network state for given values of input variables take the following form:

R^j : If FC is W^j and OSC is X^j and CPP is Y^j then NS is Z^j

Where
$W^j \in \{Low, Medium, High\}$,
$X^j \in \{Low, Medium, High\}$,
$Y^j \in \{Low, Medium, High\}, and$
$Z^j \in \{Stable, Unstable\}$

There are seven rules in the system, j=7. Mamdani type of inference is employed, with max and min for OR and AND operations respectively. A schematic of the system is illustrated in Figure 2. Center of Gravity (CoG) defuzzification is used for generating the crisp output, if required.

3.4 Features

FLAUM is designed considering a number of important factors like; minimum processing at routers, ability to handle multiple error conditions and customized design to make it adaptable to all types of network. These important features of FLAUM are discussed here;

- FLAUM is designed in two stages to make sure that not every change results in execution of the complete algorithm. Only when the instability becomes high then the second step is executed as it is computationally more expensive.

- Fuzzy Logic is used for detection of network state as it minimizes the requirement of storing large amount of data. Fuzzy Logic works with ranges instead of crisp values so routers do not need to maintain a lot of history data, with few recorded parameters the system performs the required task.

- FLAUM supports defining of values in terms of ranges which makes it very easy for network administrators to configure the mechanism according to their requirements with minimum effort.

- Three common error conditions in the network are handled by our approach to minimize flooding of network by routing messages in such conditions.

3.5 Case Study

We designed a simple simulator for preliminary testing of the proposed approach using C++. The simulator calculates the total number of update messages sent between routers using RIP. We collected results for comparing scenarios like; periodic + triggered updates, periodic updates only, triggered updates only and FLAUM based updates. A small network of five routers and five links has been designed. The system was tested with a number of error scenarios ranging from 5 to 10 routing table change events, with random duration between each pair of events.

The results showed that the number of messages sent using FLAUM were on average 25% less than other cases. The analysis showed what we anticipated as our approach takes good features of both periodic and triggered update mechanisms. It is intuitive that FLAUM is better than periodic update mechanism and comparable to triggered mechanism, in case of low routing table changes. On the other hand, FLAUM works better than triggered mechanism and is comparable to the periodic update mechanism when frequent changes occur. Hence, by employing the best of both the update mechanisms, FLAUM results in less number of update messages in all scenarios.

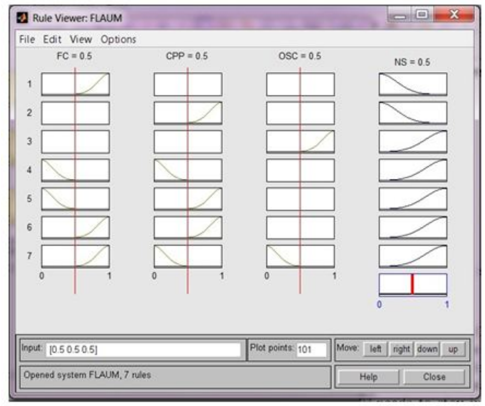

Figure 3: An Example Scenario and its Output

An example scenario is shown in Figure 3 with three input values (FC, CPP and OSC) and one crisp output value (NS). The three dimensional rule surface is shown in Figure 4 to show the rule surface of the three input variables.

3.6 Drawback

After discussing the working and design of FLAUM, it is vital to point out a drawback of the proposed mechanism. As a general design principal of the Internet, the routers have been kept as simple as possible to perform fast and effective routing. The reason is that the core routers of the backbone networks of the Internet need to process packets quickly without introducing any significant delay to the overall delivery time of the packets. This is also the main moti-

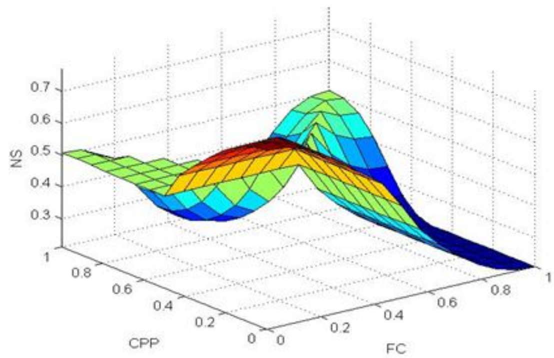

Figure 4: Rule Surface

vation to support simple and easy design of the routing protocols like RIP. However, by introducing approaches like FLAUM, routers have to do extra work, which may result in slow processing of the packets by core network routers and hence, add delay to the total delivery time of the packets. In small networks it may not be a big problem but in large networks where routers need to transmit large number of packets, this could result in degradation of overall network performance. Hence, the impact of such mechanism on the routers and network is something that needs more investigation.

4 Conclusion and Future Work

RIP is a simple routing protocol that is based on information exchange between routers. The default way to exchange routing information is by sending periodic updates, irrespective of any change in the routing table. Triggered update mechanism was proposed to enable routers to send routing messages only if there is any change in the routing table to reduce bandwidth used by these routing messages. The triggered mechanism can work well when there are few changes. In the situation of malfunctioning or configuration errors in any network entity or link, the triggered mechanism may start sending too many messages which may result in network flooding.

We have proposed a mechanism that decides dynamically on the basis of present network conditions, if triggered or periodic update messages should be sent. Our approach uses Fuzzy Logic to provide intelligence to the system with minimum computational overhead. The proposed approach, FLAUM, takes care of a number of network conditions like; router malfunctioning, other network entities malfunctioning and network reconfiguration. Preliminary simple testing of the approach has shown promising results.

An important issue that we are considering is that RIP is a routing protocol with the essence of simplicity and effectiveness. However, inherent complexities are involved in FLAUM due to the presence of intelligence. Hence, by integrating such complex mechanism with RIP, the working and effectiveness of the protocol may get affected. We believe that more thorough investigation needs to be performed on comparatively larger networks to study the effect of FLAUM on overall working of these networks.

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