스마트그리드를 위한 하이퍼큐브 스패닝 트리 프로토콜

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A Hyper Cube Spanning Tree Protocol for Smart Grid

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Abstract

It is well known that spanning tree protocol (STP) is the most commonly used protocol in switching networks for smart grid. STP selectively blocks redundancy links of the network to prevent layer 2 loops in network, and it also has a functionality of backing up links. As with the other protocols, STP has been updated with the co ntinuing development of the network. STP is a broad concept and it does not just refer in particular to def ined STP protocol in IEEE 802.1D standards, it refers to updated spanning tree protocol based on STP. Because of uneven distribution of communication traffic in root bridge, STP cannot satisfy fast converge nce while the failure occurs near the root bridge or on the root bridge in tree topologies of STP. In thi s paper, we propose a novel method --- Hyper Cube Spanning Tree Protocol (HCSTP) to solve uneven distribution of communication traffic. Theoretically, hyper cube in our protocol increases throughput and improves the utilization of communication. The simulation results show that HCSTP can achieve compar ative and considerably higher performance than other STP protocols in terms of reconnection.

Keywords --- Smart Grid, Spanning Tree Protocol, Hyper Cube

1. Introduction

A smart grid is a form of electricity network utilizing digital technology. The smart grid includes an intelligent monitoring system that keeps track of all electricity flowing in the system. IEC 61850 is a standard for the design of electrical substation automation, has been used extensively in smart grid. The IEC 61850 just supports Ethernet. Ethernet is important technology for Local Area Networks, and it is available in the IEEE 802.3 specification. Active topology in Local Area Network at any time is comprised of a set of communication paths by interconnecting LANs. Because of broadcast which switch packet, bridge via the forwarding ports and is determined by Spanning Tree Protocol (STP) [1] and its related protocols, and modifies port state information. STP discovers network loops and breaks them before they can cause damage and calculates one or more active topologies [2]. Furthermore STP is extended by Rapid Spanning Tree Protocol (RSTP) [3] and Multiple Spanning Tree Protocol (MSTP) [4]

In this paper, we propose a novel Hyper Cube Spanning Tree Protocol (HCSTP) which creates a framework of hyper cube to resolve the problem of quick connection failure occurring on the root bridge. Through hyper cube, the proposed protocol prevents the problem of low speed which is caused by the failure of the root in STP, RSTP. Furthermore, our protocol also takes advantage of MSTP which make every bridge from a tree. And combining the advantage of spanning tree protocol, HCSTP improves convergence time caused by root failure and reduces network traffic caused by lost packet.

This paper is organized as follows: Section 2 gives related works, including STP, RSTP, MSTP and hyper cube. The proposed protocol is explained in Section 3. Through the OPNET simulator we implemented and compared our proposed protocol, STP, RSTP, and the consequent result is shown in Section 4. At last, conclusions are made in the last Section.

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2. Related Works

A --- STP

One of the most important protocols of Ethernet network is Spanning Tree Protocol (STP).

The original IEEE 802.1D STP was standardized in 1998 [1].Spanning Tree Protocol discovers network loops and breaks them before they can cause any damage and therefore it calculates one or more active e topology, each loop-free subset of the physical topology

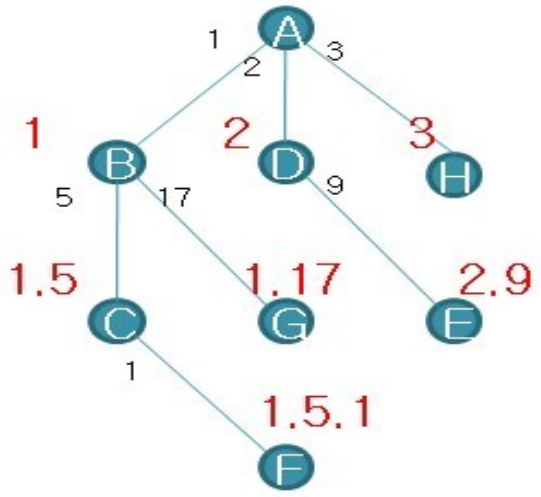
B --- RSTP RSTAA [5]

The newer version commonly used today is IEEE 802.1W Rapid Spanning Tree Protocol (RSTP) standardized in 2004 [3].

RSTP is based on the STP, the RSTP is not only able to complete all the features but also it can significantly shorten

the network re-convergence time and reduce the delay of port from blocking to forwarding when the physical topology or its configuration parameters changes. Compared with the STP, The RSTP additionally defined two kinds of type to the port which is the exchange and backup, and the three port states is defined as discarded, learning and forwarding. Different from the STP, RSTP has made some improvements on port State Migration manner, configuration message format, and the mode of the new transmission when topologies change.

This address assignment system is based on the topology of the Spanning Tree. It is based in RSTP and the relative connectivity information (BPDUs) interchanged between bridges using the designated port numbers [5]. An example is shown in Figure 1. Bridge B obtains 1 address because receives BPDUs from designated port 1 of bridge A. So, in the perspective of Bridge A. Bridge F obtain address 1.5.1.



(Figure 1) RSTAA address assignment

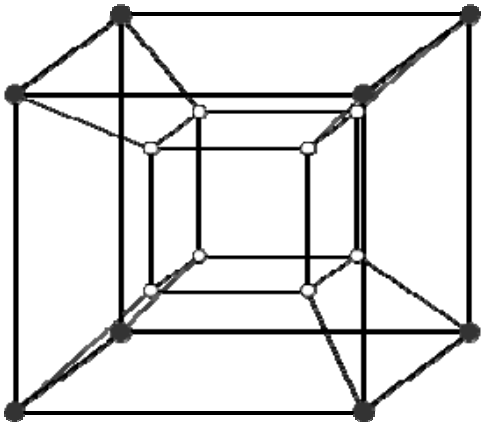
C --- MSTP

MSTP or Multiple Spanning Tree Protocol is standardized in IEEE 802.1S on 2005 [4]. MSTP uses RSTP as an underlying protocol.

In order to achieve a better utilization of the network links with a reduced complexity, the IEEE 802.1S working group has recently introduced a MSTP that allows a switch to participate in multiple spanning trees. MSTP is an extension of RSTP: it runs multiple instances of RSTP. Therefore, the transient behavior and convergence time of MSTP is the same as that of RSTP.

Hyper Cube

In this part，we briefly introduce the concept of hyper cube, and then explain how to use the hyper cube to build connected graphs. Figure 2 illustrates a complete hyper cube. An n-dimensional hyper cube which consists of N=2^n nodes is defined as a closed, compact, convex figure. Cube is a special model of hyper cube when n=3. Hyper cube has a lot of advantages such as multi-path and fault tolerance between any two nodes. And has low-density communication [6]. An n-dimensional hyper cube includes 2^n nodes and n*2^ (n-1) line segments, and can be built from a (n-1)-dimensional hyper cube [7].

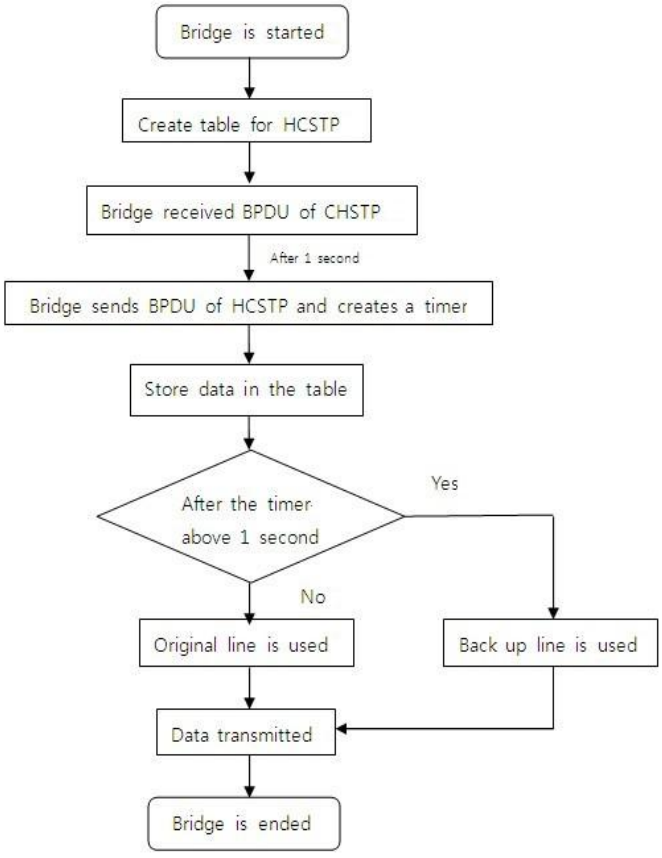


(Figure 2) A complete hyper cube of 16 nodes

3. Hyper Cube Spanning Tree Protocol

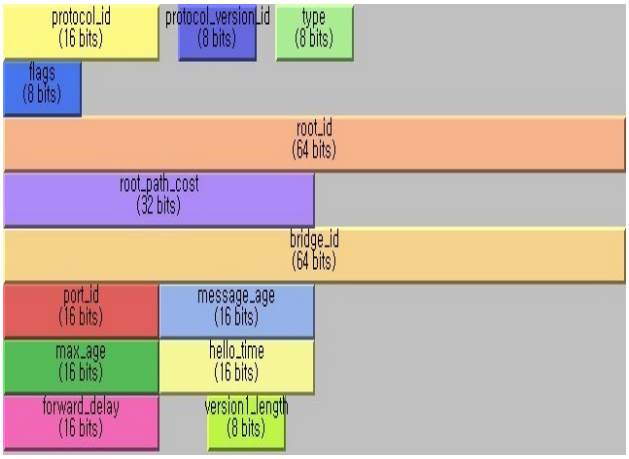
In our given network, depending on its topology the other path of spanning tree can be found and used. In order to fast convergence. We propose the Hyper Cube Spanning Tree Protocol (HCSTP) approach.

Here, we offer the HCSTP protocol which form spanning tree at every bridge. Through hyper cube in our protocol the problem of low speed which is caused by the failure of the root in STP, RSTP is prevented. Figure 3 shows HCSTP Flowchart



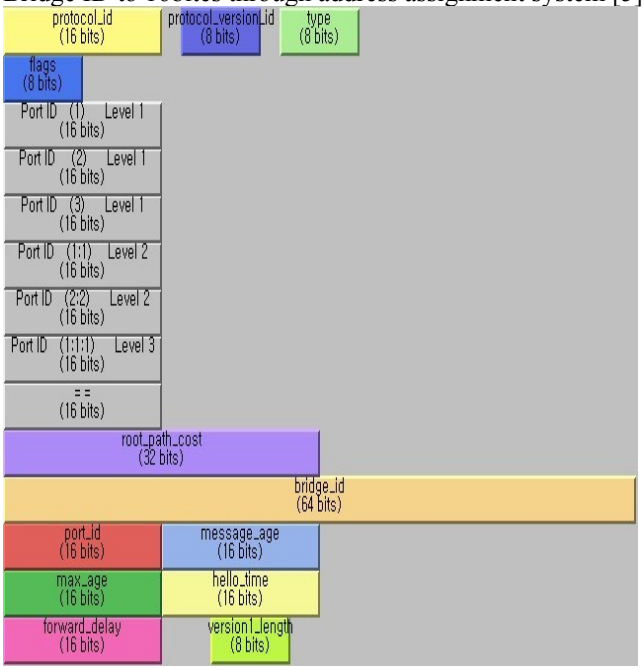
(Figure 3) HCSTP Flowchart

As we mentioned before, hyper cube has a lot of multi-path between any two nodes, so we will make a table in the bridge in older to store up two paths that are the best and shortest. One path is being using, and the other one is the backup link which will be used when the other path fails. We will get the two paths and store up into the bridge table through the Bridge Protocol Data Unit (BPDU) communication between two nodes. BPDU is a packet which is communicated by STP. It is sent by arranged interval and is used to change the information between the internet bridges. Figure 4 shows BPDU on RSTP.



(Figure 4) BPDU of RSTP

When managing table created in the bridge, lots of Bridge ID is needed to be stored up into and obtained from the table. When we write every Bridge ID into it, lots of bytes (Bridge ID = 64bites) is consumed. So we will reduce Bridge ID to 16bites through address assignment system [5].



(Figure 5) BPDU of HCSTP

In Figure 5, level is used to represent the number of hops from the bridge transmitting BPDU to the destination bridge. Through the n-dimensional hyper cube, it is derived that any distance between two nodes cannot exceed N hops. For example, in 4-dimensional hyper cube as shown in Figure 2, distance between two far most nodes cannot exceed 4 hops anyhow. This is one of the crucial reasons why this protocol uses hyper cube.

The proposed protocol adopts the way that RSTP transmits BPDU. In this way, this transmitting mechanism increase the amount of information processed, however, it brings about relatively short convergence time, so increase in the amount of information processed is acceptable. After transmitting BPDU, bridge starts a timer to observe BPDU that other bridge sends, when another bridge receives BPDU, it transmits BPDU back to other bridge after 1 second. In this way, through timer, it is known that bridge is capable of receiving BPDU from other bridge right after 1 second. In case, bridge cannot able to receive BPDU transmitted through communication line before transmitting BPDU for the next time. The bridge reckons this line as unusable for the moment and starts another back up line instantly, as a result, convergence time will be reduced to about 1 second, while the topology changes.

By using the hyper cube, every table formed in the bridge is same and helps to create and manage the tree. In Figure 6, the black part represents the red part currently used, and the path illustrates back up line.

When the path which is being using fails, the bridge will change to the backup link directly. When the bridge makes a malfunction, we can delete the error bridge and choose the other path for preparing through the modified BPDU.

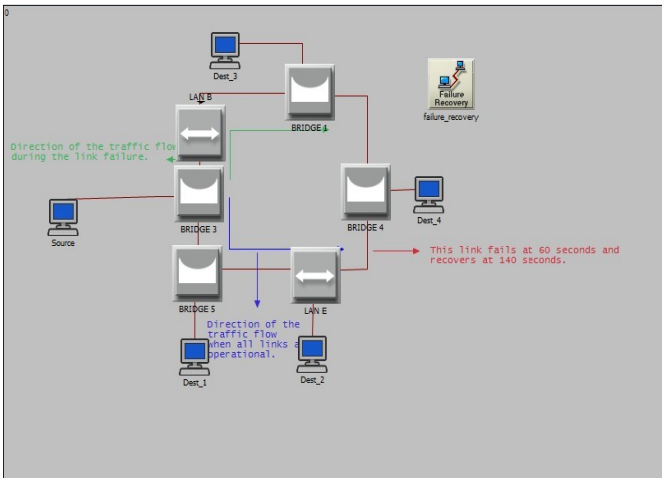
Level 1	Level 2	Level 3
B : P 1	D : P 1.1	C : P 1.1.1
C : P 2	D : P 2.2	
B : P 1	D : P 1.1	B : P 2.2.2

(Figure 6) Bridge table for HCSTP

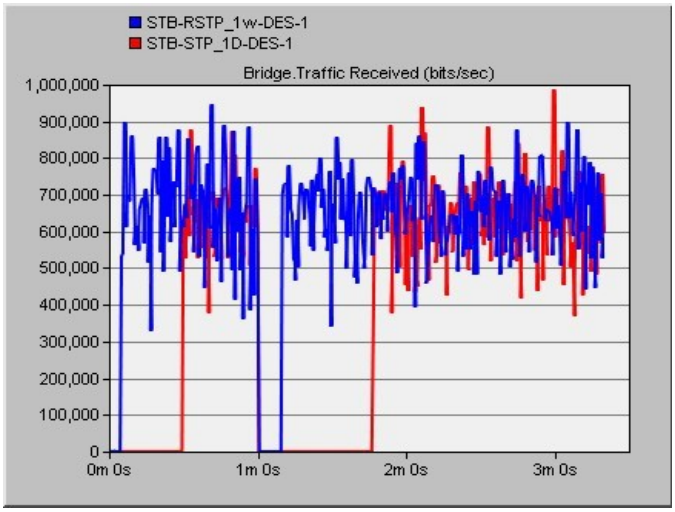
4. OPNET Simulation Results

We used OPNET as simulation tool which provides us various simulation environments to perform different kinds of experiment. We also will use 2-dimendional hyper cube to realize the protocol, as shown in Figure 7. There are 4 bridges, 2 hubs and some lines.

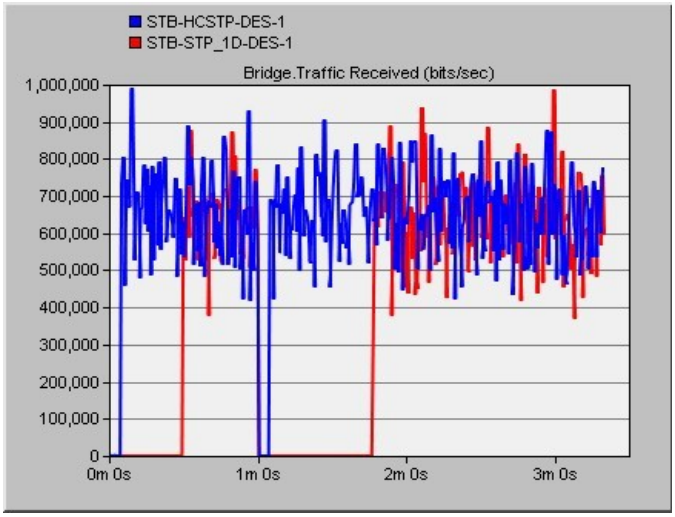
The simulation is performed as follows. Line 2 will be interrupted between 60 seconds and 140 seconds and the consequent result is analyzed.



(Figure 7) HCSTP OPNET Network Model



(Figure 8) Comparison between STP vs RSTP



(Figure 9) Comparison of STP vs HCSTP

Comparing the above two pictures, we know that the convergence speed of the tree is fast enough to near about 1 second.

5. Conclusions

In the previous research, bridge is unaware of the shape of the tree, and is only used to read the head of the message, and data is send out of the forwarding port. In this research, we suggested a novel idea, which uses mechanism of using RSTP to send BPDU. And our protocol also takes advantage of MSTP which creates several trees to make every bridge from a tree.

The proposed protocol increases throughput by building multi-path hyper cube. And combining the advantage of spanning tree protocol, HCSTP improves convergence time caused by root failure and reduces network traffic caused by lost packet.

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