L2 PROTOCOLS IN OMNET++

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L2 protocols based on STP (Spanning Tree Protocol) are right now most used for preventing L2 topology against loops in network. Nowadays also new possibilities – like SPB (Shortest Path Bridging) or TRILL (Transparent Interconnect of Lots of Links) and their proprietary variants – are being investigated to overcome some problems of STP. There is a need for suitable modeling and simulation tools supporting various L2 loop-preventing protocols in the context of different VLAN topologies. In this paper we report on our so called ANSA extension that expands INET framework in OMNeT++ environment.

ANSA extension, STP, VLAN, INET framework, OMNeT++

1. Introduction

Responsibilities of L2 layer include data delivery to/from adjacent network devices (either on point-to-point links or on shared segments), segmentation of set of hosts into VLANs and prevention against loops. Often we would like to test functionality of technologies implementing previously mentioned responsibilities in a safe environment. Simulation and modeling offer this opportunity.

Motivation behind our research, which is reviewed in this paper, is to propose architecture and create a tool capable of the following:

1) Direct communication with network devices enabling to pull/push running configuration and dynamic state from/into routers and switches.
2) Creation of a network model based on information acquired through direct communication or based on a topology description.
3) Simulation of L2 switching and data delivery using developed model including VLAN utilization, interface states and loop-preventing protocol statuses.
4) Formal verification and analysis of multicast communication models with optional recommendations how to “repair” a running configuration with respect to results.

This paper outlines main concepts of our extension called ANSA and its implementation. Our contribution provides an external tool for converting miscellaneous configurations into the unified form named ANSA Translator. Implementation output consists of source codes of new simulation model named ANSA Switch extending INET framework in OMNeT++ environment for various L2 protocol support.

1.1 Structure of paper

This paper is organized as follows. Next subsection provides a quick overview of existing tools and simulation models for multicast networks. Section 2 discusses our ANSA extension in detail. Section 3 gives notes on the implementation and presents a simple test scenario. Section 4 summarizes this paper and proposes future work.

1.2 State of the art

Functionality of upper layers is dependent on lower ones (in our case L2 layer) in ISO/OSI model of Internet. Hence VLANs utilization and status of STP-based protocols or interfaces is one of the most important information provided by network monitoring tools. Either proprietary solutions (e.g. HP Network Node Monitor [1]) or platform and vendor independent tool (e.g. PRTG Network Monitor [2]) exist. But they are nothing more than just monitoring tools.

Various L2 protocols simulation models are built into a few discrete network simulators. NS2 node concerns only about L3. OPNET supports VLANs and PVSTP+, MSTP and RSTP. Nevertheless, those simulators lack tracing of data flows, and more importantly there is no implementation of TRILL or SPB whatsoever.

Current status of L2 technologies according to our knowledge in OMNeT++ 4.2 and INET 20111118 framework is following. Right now only prototypes of compound modules `EtherSwitch` and `EtherSwitch2` are available for half and full-duplex port operations capable of basic relaying of frames implemented by `relayUnit`.

Our main goal is to offer OMNeT++ community new source codes of models that will support various L2 protocols.

2. Design

In this section we explain parts of our ANSA extension, briefly describe their functionality and design principles behind.

The first part consists of a translator from a vendor specific running configuration language to a universal configuration in XML form and its component to get relevant current state of existing network devices via SNMP. The second part discusses our own models of ANSA Router and ANSA Switch focusing on ANSA Switch design and its functionality.

2.1 ANSA Translator

Whenever we want to model a real network with routers and switches, we need firstly to determine devices participating in simulation and describe their interconnections, and secondly to pass on setup of those devices onto their counterpart models.

ANSA Translator is our tool (more details e.g. [3]) implemented as add-on to ANTLR [4]. It is able to successfully accomplish the previous two steps. ANSA Translator can translate relevant parts of running configuration of each device (even from different vendors) to unified XML form. It can also extract dynamic state of device (i.e. current content of CAM or routing table) with the help of SNMP. Based on provided topology information – either obtained automatically or fine-tuned by network administrator appropriately to real network situation – ANSA Translator can generate an OMNeT++ network description file (`.ned`) that defines a corresponding simulation model.

2.2 ANSA Switch

In order to model active network devices and simulate their behavior in a real network we have created new simulation models – ANSA Router and ANSA Switch. Functionality of those modules is continually extending with ongoing development.

ANSA Switch is additional compound module enhanced by L2 technologies that can be used as independent network node or can be inserted between interfaces and `networkLayer` of ANSA Router, which creates L3 switch. We have decided to implement L2 protocols support in OMNeT++ with respect to:

- Concept of VLANs and STP-based protocols – STP (IEEE 802.1{d,q}), MSTP (IEEE 802.1{s,q}), RSTP (IEEE 802.1w) and PVSTP+;
- VLAN management – MVRP (IEEE 802.1ak) and VTP;
- Future L2 loop-prevention protocols – TRILL (RFC 5556 and RFC 6325) and SPB (IEEE 802.1{ad,aq}).

Figure 1 shows the structure of ANSA Switch as independent network node corresponding to L2 switch. Table 1 contains brief description of each component from the bottom to the top in proposed switch architecture.

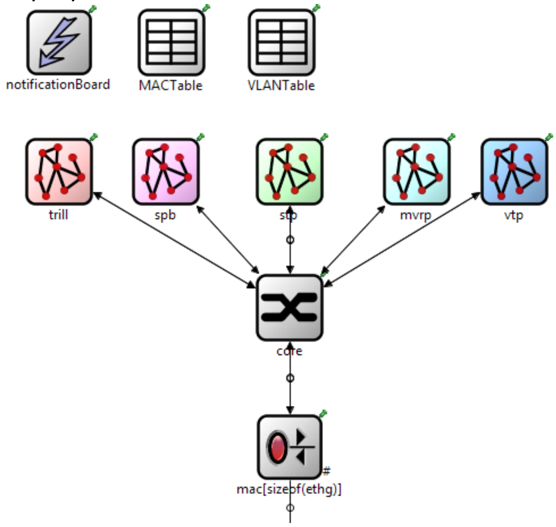

Figure 1 ANSA Switch componental structure

Table 1 ANSA Switch components description

Name	Description
`core`	Implements forwarding process and switching of Ethernet frames between interfaces and VLANs according to IEEE 802.1D.
`trill` and `spb`	Purpose of ANSA Switch is to implement future L2 loop-preventing protocols like TRILL and SPB along with traditional STP.
`stp`, `rstp`, `mstp` and `pvstp+`	Compound parental `stp` module implements behavior of all STP-based protocols. Modules for each variant are inside it.
`mvrp` and `vtp`	Those modules support VLAN management protocols.
`MACTable`	`MACTable` implements CAM table of every switch.
`VLANTable`	Compound model for VLAN-interface mapping.

3. Implementation

In this section we will deal with our VLAN and STP implementations in ANSA Switch; regarding to this, more details could be found in [5].

3.1 VLAN and STP

Spanning-Tree Protocol (STP) prevents loops from being formed when switches are interconnected via multiple redundant paths. VLAN segmentation of hosts helps to separate them into different broadcast domains usually based on their purpose or locality in network. The following three modules are important for implementation of VLAN segmentation and basic STP behavior.

Every record in `MACTable` consists of MAC address (as primary key), destination port(s), time of insertion and type of record.

`VLANTable` consists of two abstract structures. The first maps VLANs to ports and contains the information whether target VLAN should be carried in tagged or untagged frame when traversing port. The second associates port to target VLAN. The reason why the same information is stored in two separate structures consists in improving time performance when using search, insert and remove functions in different parts of forwarding process.

The whole forwarding process of frame switching is initiated upon arrival of frame according to IEEE 802.1D in `core` – including active topology enforcement, MAC learning, VLAN tagging and frame relaying (forwarding, broadcasting and discarding).

3.2 Testing scenario

We have created simple three switches, two VLANs and nine host's scenario. The goal was to proof STP topology convergence (mainly port states). Besides that also verification of proper host's communication in VLANs – more precisely ping communication between Host1-Host4 and Host3-Host7 – should be invisible for other hosts in different VLAN. Final state of simulation is depicted on (port roles are same for both STP instances) and bellow the picture brief simulation description follows:

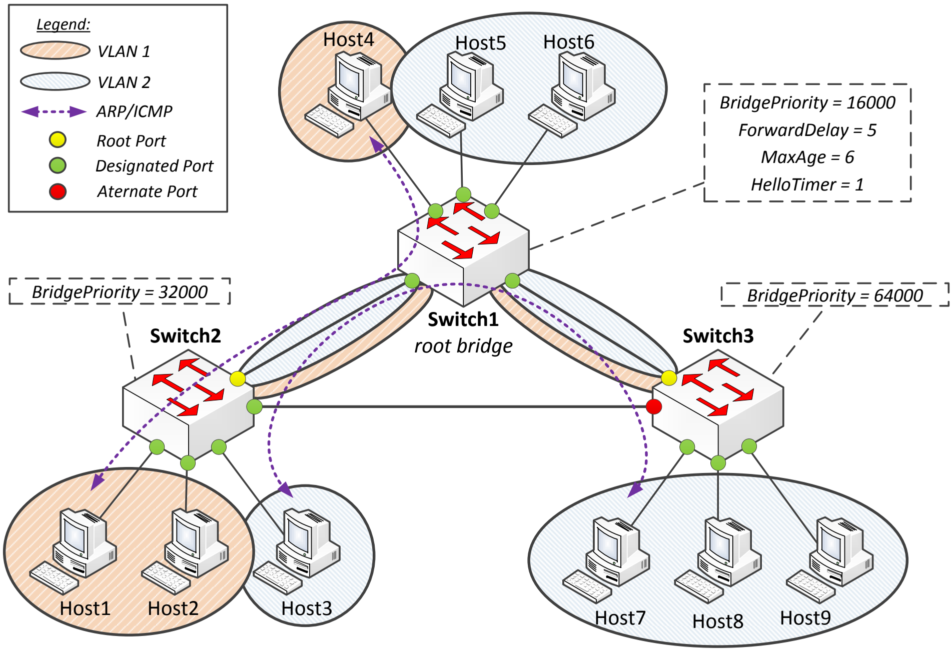

Figure 2 STP and VLAN testing scenario

1) All switches believe that they are root bridges upon initialization;
2) All ports transit from *Discarding* to *Learning* state in 15 seconds and start exchanging BPDUs;
3) After another 15 seconds Switch1 is elected as a root bridge; all ports transit to *Forwarding* state except port on the Switch3 facing Switch2 which transits to *Blocking* state; switch's port roles are marked on above the picture;
4) Pinging between hosts is scheduler after 1 minute from the start of the simulation. *ARP Request/Reply* precedes pings between Host1 and Host4 and later Host3 and Host3. Broadcasted ARP messages traverse only in appropriate VLANs and they are separated from hosts in different VLAN.

Results of simulation – timing and proper order of STP and ARP messages exchange – were successfully checked against the same real topology thus proving correctness of our implementation.

4. Conclusion

In this paper we discuss current options in modeling of L2 technologies. We give overview about existing proprietary tools and the "status quo" of this issue in the OMNeT++ environment. We unveil our ANSA extension and its two distinctive parts. The first one is a general translator and automated simulation generator called ANSA Translator. The second part is a description of simulation model of ANSA Switch – its componential structure and current functionality regarding to INET framework and

OMNeT++. The present simulation experiment focuses on VLAN and STP support. The results demonstrate success in first steps of proposed architecture implementation.

4.1 Future work

We will aim at following tasks in upcoming months of the ANSA Switch development process:

- To implement other L2 loop-prevention protocols – we are now working on TRILL, and the next will be SPB.
- To extend STP functionality – it means to implement other STP variants like PVSTP+, RSTP, MSTP and others.
- To implement management of VLANs and trunk negotiation on interfaces – we want to start with implementing of MVRP.
- To focus on real-world simulations – it requires whenever implementation of all L2 loop-preventing protocol is finished, we want to compare them and validate their functionalities on real-world scenarios.

4.2 Additional authors and acknowledgement

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