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Semi-physical Simulation Platform Research based on Ethernet Train Backbone Network

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Abstract: The IEEE61375 2-5 (Ethernet train backbone network) which is the next generation of train network protocol is the international standards promulgated by the end of 2010. The CRH3 train network topology which is based on the Ethernet Train backbone is constructed. The train inauguration procedure and the train network initialization is fulfilled. The NETFPGA is built the 4 motor and 4 trailer of CRH3 train network semi-physical simulation platform and successfully implements Ethernet train backbone network communication protocols. A communication model of car equipment and redundancy switching between working network and backup network in the MAC layer is built. The results which come from the simulation testing of the train network platform show the network performance indicators of real-time, packet loss rate, delay. It provides a useful reference data for the design of the actual train network.

Key words: Ethernet train, backbone network train, inauguration procedure, redundancy switch, optimal scheduling

INTRODUCTION

Current CRH2 and CRH3's network, respectively using the ARCNET and the TCN protocol in China. The TCN has two serial master-slave bus: Train Bus (WTB) which is used to interconnect with vehicles, a variety vehicle bus (MVB) and the vehicle equipment, do self-configuration (Moreno *et al*., 2007; Zeng *et al*., 2010).

Due to the unique advantages of the Ethernet network communication and wide range of applications in various fields, more and more automation industry research to high-speed Ethernet equipment to factories and train equipment (Jun-Jie *et al*., 2006). Recent Fast Gigabit Ethernet, as well as more reliable Ethernet switch has more application. With the development of intelligent integrated railway system project in Europe. The train builds dynamic information node, applies to the ground control center and communicates with passengers. At the same time there are more and more network applications in train, such as PIS (Passenger Information System), flat panel CCTV, passenger entertainment, which requires increasing network bandwidth. Obviously, the traditional WTB bandwidth with only a few megabits is not enough to support such applications (Jun-Jie *et al*., 2006).

The International Electrotechnical Commission (IEC) develop a specification of railway vehicle equipment data communications standards and provides a good theoretical basis and foundation of Ethernet train Backbone. The Backbone so as to achieve interoperability between consists of different types when coupled in the same train composition. Since it is a set of protocols developed for vehicle control, compared to the other network protocols, the train has a very distinct advantage (Jensen, 1994). Ethernet train backbone network has become an inevitable trend of the next generation of train network control (Verstoep *et al*., 2009).

Some research of the Ethernet train backbone network is its initialization (T2DP) protocol (Wei *et al*., 2010), there are also a pure software emulation performance of Ethernet train backbone network, i.e., OPNET simulation analysis (Jimenez *et al*., 2003) but semi-physical simulation the first time.

The Ethernet train backbone network protocol is being used in the CRH3 instead of train bus (WTB) and built semi-physical simulation platform. The simulation results is being analyzed which will have a positive meaning for the train Ethernet train backbone network extending to the vehicle, the platform and even equipment in the train.

ETHERNET TRAIN BACKBONE NETWORK PROTOCOL ANALYZE

ETB use physical links along the train to connect the active network devices together. These links are also called physical segments, and shall use passive component as cables and connectors, dedicated to Ethernet.

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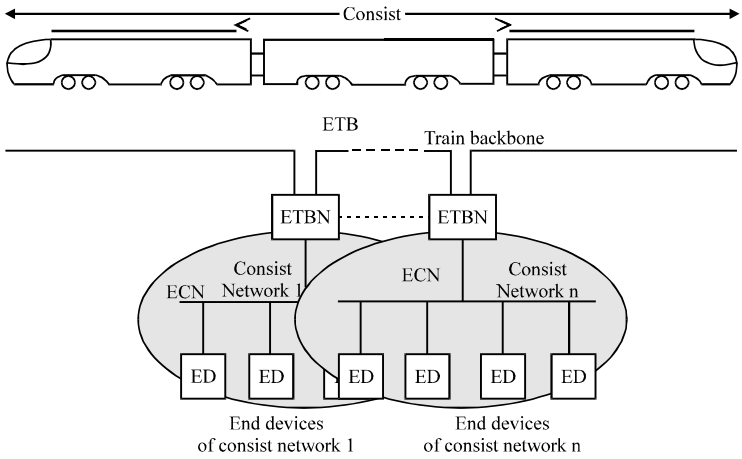

Fig. 1: Train Ethernet topology

As describe in the document IEC61375-1, consist topology shall be hierarchical with one or more train backbone subnet (ETB, Ethernet Train Backbone) and one or more Consist Network subnets.

As shown in Fig. 1, every train compartment is seen as a network node (ETBN). The network nodes are simulated with NetFPGAs. The ETBNs are connected one by one to built a linear topological network. There could be different kinds of end devices or communication devices in individual ETBN.

ETBN, IP addresses on ETB side are defined as below:

00001010 .1bb00000.00tttttt.hhhhhhhh/18

As describe in Table 1, [b] part in subnet IP addresses means <<backbone id>>. There are four kinds of values to classify information types. 00 represents train control messages. And 01 means multimedia informations. The 10 and 11 could be reserved for other uses. [t] part in subnet IP addresses means <<ETBN id>>. It is an inauguration result and also the ETBN number inside the train. [h] part means <<host id>>. It is an unique host identification for ETBN node.

Train inauguration is based on a specific protocol: Train Topology Discovery Protocol (TTDP). All ETBN shall implement TTDP.

The action consisting to configure the train network is called train inauguration. Normal inauguration occurred at power up time but also when shortening or lengthening a train. To keep IP stability, inauguration due to degraded mode shall be avoid (losing ETBN, late ETBN insertion). Best train IP configuration shall always be computed, updated and shared by all ETBN at any time, but decision to apply it (launch inauguration procedure) shall always be under train application control.

Table 1: Train subnet decomposition

Parts	Description
[b]	Backbone id, between [0, 3]. Identify some train backbone subnets. 0, for TCMS 1, for multimedia 2, not specialized 3, not specialized
[t]	ETBN id Never Null, between [1, 63]
[h]	host id Up to 254 hosts by ETBN node available

The train inauguration procedure needs an identification number for each CN subnet and each ETBN. These values shall be used to build train IP mapping, train routing definition, NAT rules etc. Compute these identifiers is the main goal of TTDP: Train Topology Discovery Protocol (Mitra, 2008).

To determine these values, two types of topology are built by TTDP:

- **Physical topology:** Ordered and oriented list of ETBN. Train physical topology is defined inside an array: the "Connectivity Table". Physical topology is always updated to follow the number of ETBN connected to ETB. All ETBN Shall be detected (master or backup node). It could be notice that a new physical topology doesn't imply a new inauguration. To have a new inauguration train application shall enable it
- **Logical topology:** Ordered and oriented list of train subnets. Train logical topology is defined inside an array: the "Train Network Directory". Logical topology contains "subnet id" and "ETBN id". It could be notice that some identifiers are reserved by TTDP for missing ETBN or CN subnet

ETB TRAIN INAUGURATION: TTDP

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SEMI-PHYSICAL MODEL

The article uses Ethernet train backbone network communication simulation platform equipped NETFPGA.

The NETFPGA is a low-cost platform, primarily designed as a tool for teaching networking hardware and router design. It has also proved to be a useful tool for networking researchers. At a high level, the board contains four 1 Gigabit/second Ethernet (GigE) interfaces, a user programmable Field Programmable Gate Array (FPGA) and four banks of locally-attached Static and Dynamic Random Access Memory (SRAM and DRAM). It has a standard PCI interface allowing it to be connected to a desktop PC or server.

The NetFPGA platform contains one large Xilinx Virtex2-Pro 50 FPGA which is programmed with user-defined logic and has a core clock that runs at 125 MHZ. The NETFPGA platform also contains one small Xilinx Spartan II FPGA holding the logic that implements the control logic for the PCI interface to the host processor, as shown in Fig. 2.

There are four 1000 M Ethernet ports in NetFPGA board (Port0, 1, 2, 3). Port0 and Port1 are, respectively connected to the right neighbor ETBN and left neighbor ETBN. So NetFPGA only needs two ports to built the linear topology. While the Port2 and Port3 could be used for redundancy switch function.

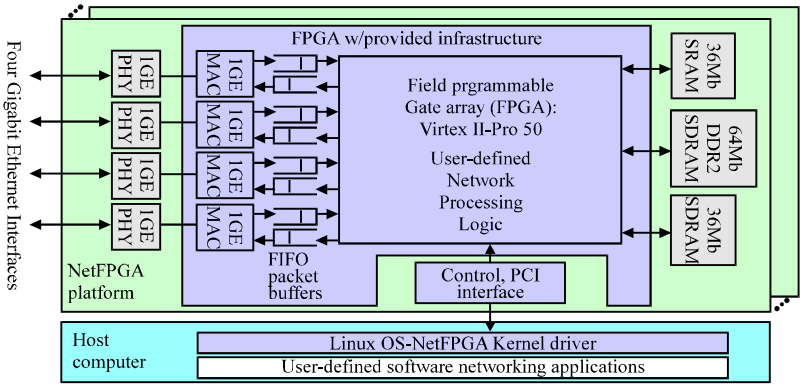

Fig. 2: NETFPGA hardware diagram

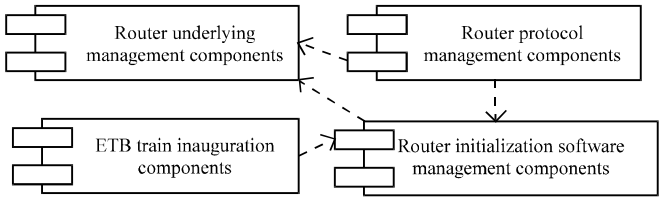

Fig. 3: Ethernet train backbone network package UML

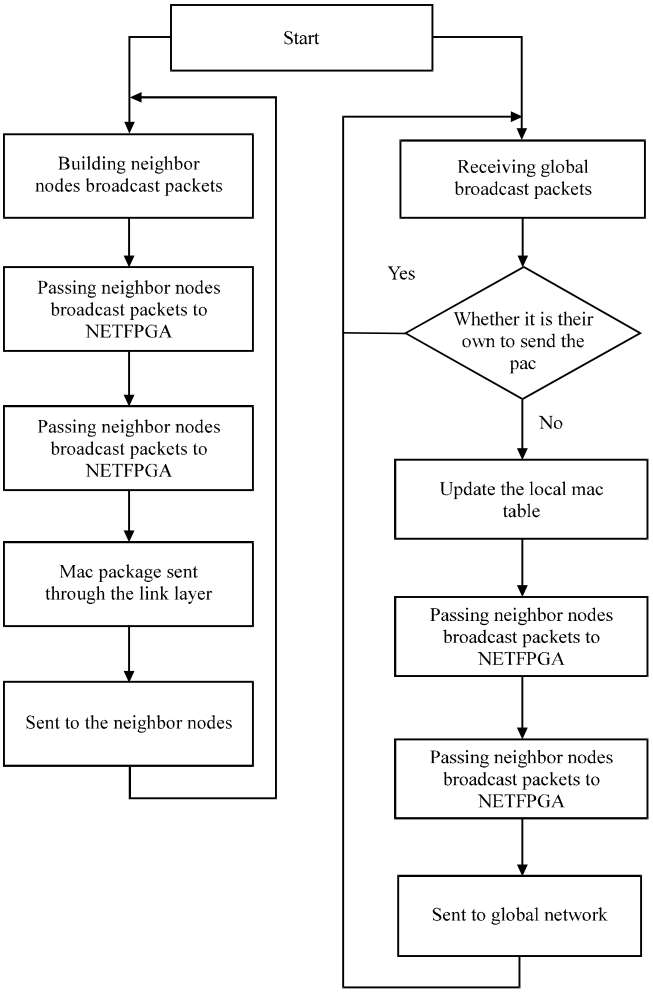

Fig. 4: Ethernet trains initiation protocol flowchart

ALGORITHM DESIGN

Ethernet train backbone network design: This simulation platform is based on CRH3 train network, the main object is the train backbone network which is composed by a number of backbone nodes. Each backbone node functions are as follows: Transmission and process the entire network data, fault information and driver operation.

When the trains' backbone node failure during the transition will affect the entire network status information and control instructions. In order to improve the reliability of the entire network data transfer, redundant switching technology is used in the train backbone nodes, that is, when the backbone nodes failure, the hot standby node monitoring the backbone node failure, then immediately start to take over all the work of the backbone nodes, making the entire network of data transmission without affecting.

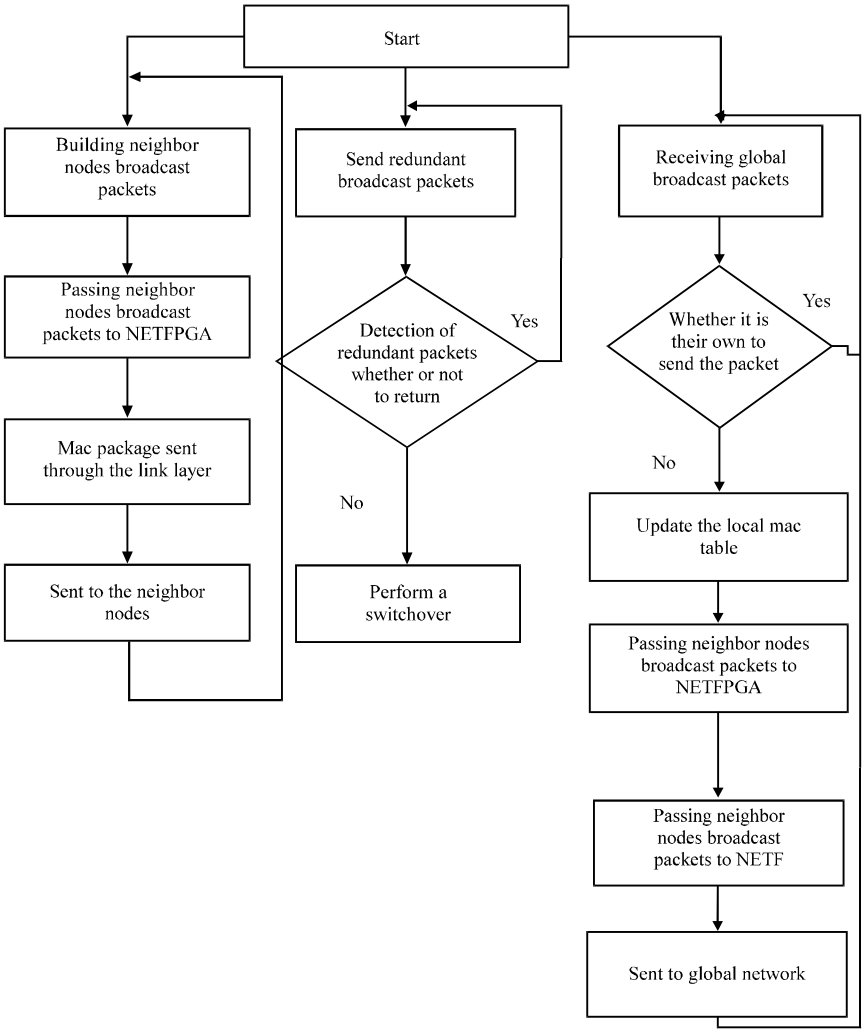

Fig. 5: Redundant switching function trains initialization flowchart

Measure the performance of the network by connectivity, throughput, bandwidth, packet forwarding rate, the utilization of the channel, the capacity of the channel, bandwidth, packet loss, packet loss rate, propagation delay, reliability and other indicators form.

This platform also requires a certain degree of scalability. After the release of 61375-3-4 which is the electrical equipment and systems for railways, it will joint commissioning, to get a more complete Ethernet train network.

Ethernet train backbone network use network simulation software packages: the decomposition use the rule of package-components-modules which rely on their own function. Ethernet train backbone network simulation package is divided into four components and the specific components shown in Fig. 3.

Ethernet train the backbone network TTDP protocol packet forwarding software flowchart TTDP protocol packet transmission process, as shown in Fig. 4 and 5.

NETWORK PERFORMANCE SIMULATION RESULTS

The NetFPGA Port0 and Port1 send and receive data packets circumstance shown in Fig. 6. The data part a in Fig. 6 presents data packets received situation of Port0. Part b presents data packets sent situation of Port0. Part c presents data packets dropped situation of Port0. Then the part d, e, f, respectively present the Port1 data packets received, sent and dropped situation. The data packets could be sent and received very correctly and no packets dropped.

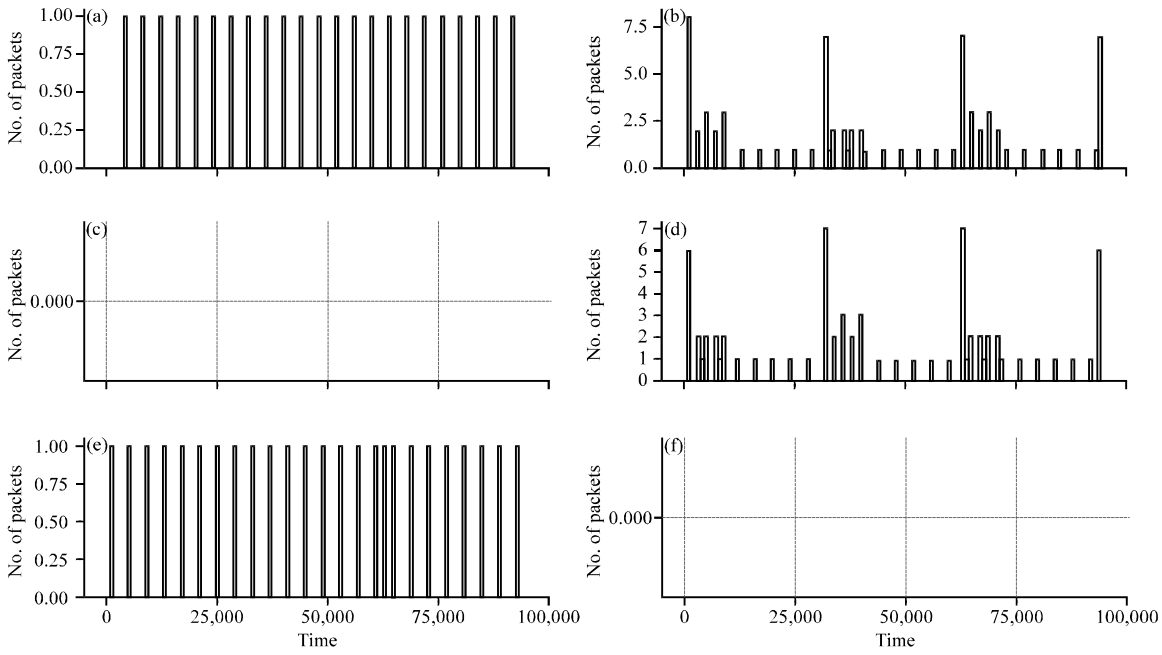

Fig. 6(a-f): NETFPGA network port statistics, (a) Port 0 Pkts Rcvd, (b) Port 0 Pkts Sent, (c) Port 0 Pkts Dropped, (d) Port 1 Pkts Rcvd, (e) Port 1 Pkts Sent and (f) Port 1 Pkts Dropped

Table 2: The loads of train nodes

Train network nodes	Delay time (us)	Flow (KB sec^{-1})
One node	57	163
Two nodes	57	326
Four node (balance load)	57	652
Four node (unbalance load)	62	652
Eight nodes (balance load)	62	1300

Table 3: Single-node load capacity measurement

A node load (packet)	Packet's length (byte)	Time delay (us)
1000 sec	1000	55
2000 sec	1000	56
2800 sec	1000	56
3600 sec	1000	56
4800 sec	1000	56
10000 sec	1000	56
25000 sec	1000	60
48000 sec	1500	60

As shown in Table 2, the ETBN's delay time could be under 62 us while the flow could be over 163 kbps in one node mode. So the ETBN network loads reflect very highly performance.

As shown in Table 3, single-node load increased to 48000 packets (1500 bytes/packet) in 1 sec. While the time delay still did not exceed 60 us. So, the ethernet train backbone network comparing the bandwidth of TCN network, has a strong ability to deliver more data and to achieve real-time requirement.

CONCLUSION

The CRH3 network communication systems is simulated, communication data dived into process data, message data, flow data, best-effort data, regulatory data. Through the platform of the test, the new train backbone network protocol IEC61375-2-5 has a better performance in reliability, delay time, throughput, bandwidth utilization, packet loss while comparing the TCN network in the WTB network which has only 10 M sec^{-1} of bandwidth. The new train backbone network will undoubtedly have better network connectivity and load capacity. It is the trend of the development of a new train network.

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