Analysis of industrial Ethernet POWERLINK multimaster redundancy

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Abstract

This paper describes the Managing Node (MN) realization method of redundancy in the Ethernet POWERLINK network. Through the monitoring network and control information updating to achieve the MN redundancy function. We give priority algorithm of redundant switching. The MN redundancy ensures the POWERLINK cycle production continuance after the failure of the current master station, the switch-over time (recovery time) of the POWERLINK system is in the two POWERLINK cycle time at least. That ensures a very fast restoring of normal operation without any downtime for the control system.

Keywords: redundant managing node, network monitoring, control information updating.

1 Introduction

With Ethernet POWERLINK (EPL) high availability, the availability of the system is ensured in the event of a component failure. Both the nodes and medium redundancy prevent having a single point of failure in the system.

In this paper, we focus on the redundancy of Managing Node Industrial EPL. The redundancy of a Managing Node (MN) is achieved with several Redundant Managing Nodes (RMNs) being deployed in the network. The POWERLINK network is monitored from them, and due to predefined specifications one of them can take over the role of a MN in case the Active Managing Node (AMN) fails, the MN continues to keep the POWERLINK network normal work.

The RMN has two states: standby and active. An RMN in an active state is called “Active Managing Node” (AMN). When an RMN in a standby state, it is called “Standby Managing Node” (SMN). An AMN behaves like an MN, and an
SMN normally like a controlled Node (CN). The only difference between an SMN and a CN is the monitoring of the POWERLINK network traffic.

2 The EPL protocol

The EPL communication profile is shown in Figure 1. EPL extends Ethernet according to the IEEE 802.3 standard with mechanisms to transfer data with predictable timing and precise synchronization. It comprises five additional fields which have been allocated in the first three bytes of the data field of the IEEE 802.3 original frame [1]. The communication profile meets timing demands typical for high-performance automation and motion applications [2]. It does not change basic principles of the Fast Ethernet Standard IEEE 802.3 but extends it toward RTE(Real-Time Ethernet).

An MN, which acts as the master in the EPL network, polls the CNs cyclically. This process takes place in the isochronous phase of the EPL cycle. Immediately after the isochronous phase an asynchronous phase for communication follows which is not time-critical, e.g., TCP/IP communication. The isochronous phase starts with the Start of Cyclic frame on which all nodes are synchronized. This schedule design avoids collisions which are usually present on Standard Ethernet, and ensures the determinism of the hard real-time communication. It is implemented in the EPL data link layer. The EPL network can be connected via gateways to nonreal-time networks.

![Figure 1: EPL communication profile.](image)

The communication profile of EPL is adapted from CANopen. Thus, design principles such as process data object (PDO) for the exchange of process variables and service data object (SDO) for the configuration of remote object dictionaries are reused. All PDOs are exchanged within the isochronous phase,
similar to the synchronous PDOs of CANopen. This is because event-triggered PDOs would interfere with hard real-time requirements.

3 MN redundancy

The RMN network is shown in Figure 2. The RMNs monitor the POWERLINK network activity. If no activity is detected, the RMN will enter in the state active mode, it will change to MN and to manage the POWERLINK network. The EPL application must be seamless docking.

A very critical phase in the POWERLINK network is the takeover of the active MN function by the SMN. During this time, it must be guaranteed that all of the CNs remain fully functional. During and after the switching, the CNs are not allowed to leave their Operational State, and de-synchronize themselves. This shall be achieved with the use of an identical network configuration for all the RMNs. Another crucial is that when an RMN takes over the task of an AMN, this must take place without going through the boot up procedure. Therefore, the RMN must be capable of monitoring the POWERLINK network during the standby phase, to gather information about the connected CNs. Therefore, the RMN major function can be divided into network monitoring and data refresh.

![Redundant network topology](image)

3.1 Network monitoring

The RMNs will get information from the other nodes by listening to the frame message of EPL in the network. The SMNs listen to the SoC frame and SoA frame of the AMN, if SoC or SoA are not detected on the bus, one of the SMNs becomes an AMN. Then it will start producing SoCs beginning with the next scheduled cycle, directly into the POWERLINK cycle communication state of wholeness. Continue to control the whole POWERLINK network normal operation.
3.2 Control information updating

In the POWERLINK network, process variables and control variables of the MN user application definition are referred to as control information of master station. In order to make the SMN can continue to control the normal operation of network failure in an operational state. It is important that the control real-time information be preserved.

In order to preserve the control real-time information, we need to listen to the Preq frame from the AMN. Use the Preq to refresh the local SMN control information. A necessary condition for the realization of this course is the user’s control information to all mapped into sending object dictionary. This comes from AMN Preq to carry control information of all the current network state, and the control information refresh control information of SMN the same user’s application defines the mapping object dictionary, and then returning from the CN data through the Pres updates. The RMN switching is shown in Figure 3.

How to realize the Preq refresh transmission part of the object dictionary function, this need to increase the transmitting part of object dictionary new at the data link layer to update processing module. In order to make the change mechanism of station control data in redundant switching around is consistent, the RMN active record at the breakpoint communication from the CN number, RMN shall establish a response from a no communication from the station start, this will ensure that the master of the control mechanism of station has not changed.

![Figure 3: Master redundancy switching.](image)

3.3 Election mechanism

Only one RMN is allowed to become an AMN, assuming the presence of more than one RMN, which requires a suitable election mechanism. The election mechanism is based on priorities assigned to each RMN. The RMN shall have a unique priority, thus the election mechanism will ensure that the RMN having the highest priority will become AMN in case of failure of the current AMN. The default priority, based on the unique Node ID, is given to each RMN. In this case each RMN shall have a unique Node ID from 241 to 250.
During the RMN boot process the POWERLINK network is monitored by the MN for a period of time, given by the object NMT_BootTime_REC.MnWaitNoAct_U32 (index 1F89h, sub index 01h) to determine whether there is another RMN active on the bus. A suitable configuration tool will initialize this object in each MN across the network to achieve a de facto priority for an MN to boot the network.

In the states where the AMN produces a reduced cycle each SMN will start the timer \( T_{\text{switch}_{-}\text{over}} \) on SoA reception. If this timer expires, the SMN with the highest priority will broadcast an Active Managing Node Indication (AMNI) message and will switch to become an AMN. Then it will start producing POWERLINK reduced cycles beginning with the next scheduled cycle.

\[
T_{\text{switch}_{-}\text{over}} = \text{MnWaitNoAct } _{\text{U32}}
\]

In states where the MN produces SoCs the SMN will implement a timer \( T_{\text{switch}_{-}\text{over}} \) to be retriggered on reception of an SoC. Should the timer expire, the SMN with the highest priority shall broadcast an AMNI message and shall switch to become an AMN. Then it will start producing SoCs beginning with the next scheduled cycle.

The POWERLINK cycle is divided in \( \text{MnSwitchOverDivider}_ {\text{U32}} \) slices, the difference of \( T_{\text{switch}_{-}\text{over}} \) between two nodes will be at least one slice. The timer value will be computed by each SMN on the following way:

\[
T_{\text{soc}_{-}\text{switch}_{-}\text{over}} = T_{\text{cycle}} + [(\text{MnSwitchOver Priority } _{\text{U32}} + \text{MnSwitchOverDelay } _{\text{U32}}) / \text{MnSwitchOverDivider } _{\text{U32}}]
\]

where \( T_{\text{cycle}} \) is the POWERLINK cycle length (Object NMT_CycleLen_U32).

\( \text{MnSwitchOver Priority } _{\text{U32}} \) is the priority of the node at switch-over (the highest priority node should take over the bus when the AMN fails).

\( \text{MnSwitchOverDelay } _{\text{U32}} \) is an optional delay added to \( T_{\text{soc}_{-}\text{switch}_{-}\text{over}} \) to give a lower priority to a node which is not yet ready to switch-over.

\( \text{MnSwitchOverDivider } _{\text{U32}} \) indicates in how many slices the cycle will be divided, the difference between \( T_{\text{soc}_{-}\text{switch}_{-}\text{over}} \) for every node will be at least one slice of the cycle time.

The configuration tool must ensure that all \( T_{\text{soc}_{-}\text{switch}_{-}\text{over}} \) values for all nodes are unique. In addition to the subindices of the object NMT_BootTime_REC defined in the POWERLINK specification, the following subindices will be implemented in an RMN.

### 4 Multimaster redundant test

In this test, there are two PC master stations in the POWERLINK network. They have a unique MAC address. The CNs have to be configured in a way that they tolerate the loss of at least two communication cycles. The RMN at switch-over is
shown in Figure 4. We use Wireshark for the analysis of POWERLINK network data packets. Wireshark is a network packet analyzer, the network packet analyzer will try to capture network packets and tries to display that packet data as detailed as possible.

The EPL communication cycle time is 10 ms. The RMN switching time is shown in Figure 5, this switching time is in the two EPL cycle. As can be seen, there is a complete switch-over between the two RMNs. The SMN monitors the network to detect the loss of the current MN, as a matter of fact, the detection of the AMN failure leads to have a missing SoC frame in this network. The SMN broadcasted an AMNI message, which entered operational state, and taken over the current network.

Redundancy switch at the breakpoint occurred, SMN took over the network. Starting from the original communication station did not complete the control node data exchange. This ensures the consistency of the original control system of state.

5 Conclusion

The MN redundancy ensures the POWERLINK cycle production continuance, which keeps synchronicity in case of MN failure. The recovery time of the system is in the range of the POWERLINK cycle time, which ensures a very fast restoring of normal operation without any downtime for the network. The multimaster redundant technology increases control system reliability and stability, which in the industrial control field has a wide range of applications.
Figure 5: EPL Redundant switching time diagram.

Acknowledgment

The research work was financially supported by the National High Technology Research and Development Program of China (863 Program) under Grant No. 2011AA040102.

References