PROVIDING GUARANTEED PACKET DELIVERY TIME IN SPACEWIRE NETWORKS

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Short Paper

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ABSTRACT

SpaceWire interconnections are used in many systems with maximal packet delivery time constraints. We consider some mechanisms for ensuring this feature in the frame of this standard, without updating the basic standard document. Delivery time for a packet depends on the packet length, SpaceWire links transmission rate, which could vary from 2 to 400Mbit/c, on the SpaceWire interconnection topology, on arbitration algorithms and buffering schemes in routing switches. We analyze characteristics of real-time packets delivery using the time-division transmission with global time-slots in SpaceWire interconnection. It is to be based on time-codes distribution mechanism in the SpaceWire standard. We estimate accuracy of global synchronization with time-codes in different interconnection topologies, its skew and jitter (time-triggered communications). Margins for time-slot specification are considered. Methods for terminal nodes distribution over the time-slots for packets transmission are considered. Interference of packets from different time-slots inside a multi-hop interconnection is estimated.

1 THE MINIMUM DISTANCE BETWEEN TWO SEQUENTIAL TRANSMISSION PHASES

The distance between two sequential transmission phases (slot (i) and slot (i+1)) typically need for avoiding situation when packets from slot i arrived to destination node too late, because they are blocked by packets transmitted in slot i+1. In worst case these packets arrives to destination node in slot (i) of next TDMA round. Also the delivery time for these packets will be essentially more than required delivery time. Let’s evaluate the minimal between transmission phases in two sequential slots for time-triggered communication. (Time-codes are used for synchronisation of terminal nodes clocks.) For these systems the minimum distance between two transmission phases is equal to the maximal distance of local clocks in the system. This distance appear because in transit switches waiting time before sending Time-code for different port (depends on transmission rate and state of previous symbol sending) is differ.

Correspondingly to system tacks and conditions of usage the transmission rate in different links could be essentially differ. Also for some tacks could be used nonsymmetrical topologies in which the ways from generator of Time-codes to other terminal nodes could have different length (different number of transit switches).

The maximal distance between sending of Time-code in one switch that is result of waiting to send previous code (Tt) is:

$$Tt = a * Tb \quad (1)$$

Where Tb – time of one bit transmission for most slowly link,
a –the number of bits in previous symbol.

The maximal length of SpaceWire symbol is 14 bits, it corresponds to Time-code, distributed interrupt code or acknowledge code. Correspondingly SpaceWire standard two Time-codes could not go to one port without big time interval. But the distributed interrupt code or acknowledge code could directly precede to Time-code. Also the value of coefficient a will be 14 for systems where the distributed interrupts and acknowledge codes are used, or 10 for systems without these codes.

The maximal delivery time for Time-code could be evaluated with using of next formula:

$$Ttd\max = 14 * Tb_0 + \sum_{i=1}^{N} (Ts + Tt + 14 * Tb_i) \quad (2)$$

where Ts – the Time-code processing time in transit switch
Tbi – the time of one bit transmission in transit link,
N – number of transit switches in the path

The minimal delivery time of Time-code to destination node could be evaluated by next formula:

$$Ttd\min = 14 * Tb_0 + \sum_{i=1}^{N} (Ts + 14 * Tb_i) \quad (3)$$

Then the maximal distance between time codes arrival times for different terminal nodes could be evaluated as:

$$Tt\max = \max_i (Ttd\max) - \min_i (Ttd\min) \quad (4)$$

If Time-codes source node could be source of packets then

$$Tt\max = \max_i (Ttd\max) \quad (5)$$

This parameter determines maximum distance of local clocks in the system and the minimal distance between two sequential transmission phases.

2 INTERVAL BETWEEN START OF LAST PACKET TRANSMISSION AND END OF TRANSMISSION PHASE

Let’s evaluate the interval between start of last packet transmission and end of transmission phase. This time is function of packet length (the length of last packet in current slot) – Zp (the number of symbols), of transmission rate in transit links (Tb), of header processing time in transit switches (Tsh), of transit switches number (N). If in one slot the transmission between some pairs of terminal nodes is allowed and transmission paths includes shared links then in corresponded transit switches we need to the – Ta. When the transmission rates of all links of the path are equal the maximal header of packet transmission is:

$$Th = 10 * Tb + \sum_{i=1}^{N} (Tsh + Ta + 10 * Tb) \quad (6)$$

The maximal interval between arriving of header and of packet end to destination node (Td) could be evaluated by next formula:

$$Td = (Zp - 2) * 10 * Tb + 4 * Tb \quad (7)$$

The whole transmission time could be evaluated by next formula:

$$Tp = Th + Td \quad (8)$$

This expression not includes time of waiting in case of header wait when transmission of previous symbol is finished. If packet length is more than 10 – 15 symbols this wait time is negligibly small. If transmission rate in different links is differ then

$$Th = 10 * Tb0 + \sum_{i=1}^{N} (Tsh + Ta + 10 * Tbi) \quad (8)$$

The time interval between arriving of the first and the last symbol of packet to destination node is strongly depends from transmission rate in most slowly link in the path. It could be evaluated by formula (7) when Tb=max(Tbi) for all links included in the path. Also in systems with different link transmission rates in some cases we need to take into account the wait time for sending the NULL inserted because the data symbol is not ready. This wait time is important if data rate of output link is bigger than data rate of input link in less than 2 times. For such transmission rates the NULL symbols will be often appear before data symbol and interval between starting of NULL transmission and time when next data symbol is ready to transmission is very short. As result the real transmission rate for output link will be less than for input link. The time interval between first and last symbol of packet in this case is:

$$Td = (Zp - 2) * 10 * Tbo + 4 * Tbo + 8 * Zp * (Tbi - Tbo), \quad (9)$$

where Tbi – the one bit transmission rate for input link,
Tbo – the one bit transmission rate for output link
The whole packet transmission time is:

$$Tp = Th + \max_i (Td) \quad (11)$$

The parameter Tp show the time before end of transmission phase when the source must start last packet transmission.

3 SOME EXAMPLES

Let's consider the system with three structure represented on figure 1. On this figure circles correspond to terminal nodes, the squares correspond to switches. The transmission rate of links between switches and link T0-S0 is 400Mbit/s (Tb=2,5нс). The node T0 is source of Time-codes and destination node for data flows from all other nodes. The transmission rate of links between nodes T1 – T40 and switches is 10Mbit/s. Let's suppose that Ts=50ns. If T0 is not packet source Ttmax= 1025 ns, in other case Ttmax=2545 ns. Let's evaluate the distance between start of last packet header transmission and end of transmission phase as function of packet size for this example. Let's suppose that every node need to transmit 512 bytes of data during one transmission phase (one slot) and only one source node exists in every phase. It could send these data as one or some packets. In this article we suppose that every packet

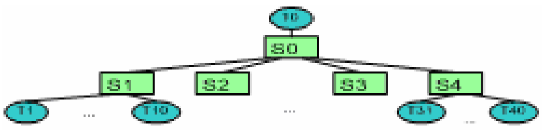
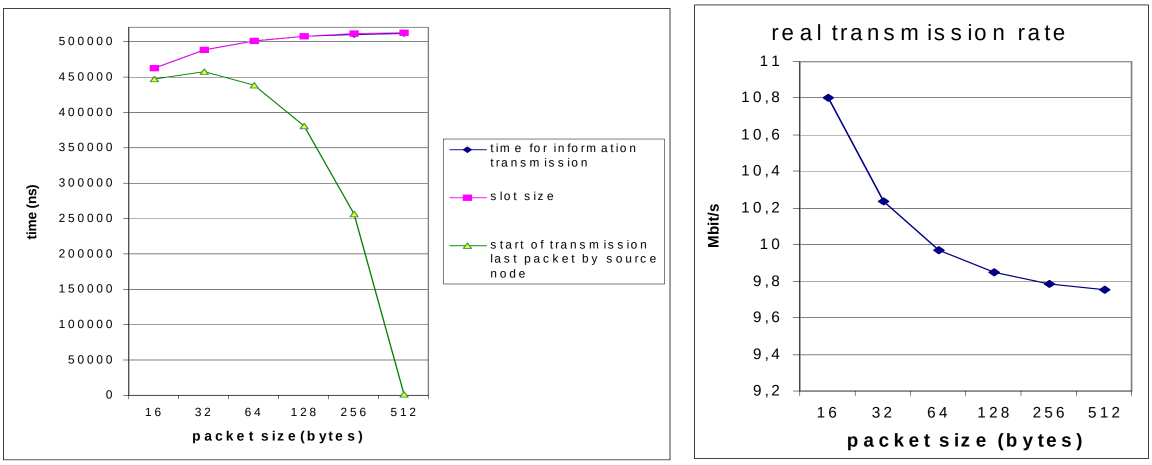


Figure 1. the example of system, based on three topology

includes only header (size is 1 byte), end of packet and data payload (we don't analyze system parameters in case of RMAP packets). On figure 2 a represented dependency between packet size and transmission phase size, whole slot size and start of last packet transmission. For this example the distance between two sequential transmission phases is very small in comparison with slot size (less, than 0.3% of slot size). The slot size grows with growing of packet size but not essentially (the difference for Zp=16 and Zp=512 is 1.1 times). On figure 2 b represented real transmission rate of link between S0 and T0. It is essentially less than physical transmission rate of this link (400Mbit/s). The length of TDMA round is from 18519000 ns to 20503000 ns dependently of packet length. Also the real transmission rate for every node is 0.28Mbit/s. For growing utilization of link between T0 and S0 we can use, for example, packet buffering in S1 – S4. This problem could not be decides only with using of different variants of slot distribution.



a) b)

Figure 2. – timing parameters for example 1

Let's consider other structure represented on figure 3. In this system T3 is Time-codes source. The transmission rate for links marked by dashed lines is 10Mbit/s, the transmission rate of other links is 400Mbit/s. The data flows represented by arrows. Ts=100 ns. For this system Ttmax=3175 ns. For this system this interval between transmission phases is not small. 126 data symbols could be sending between T3 and T2 in this period. Let's consider possible slot distributions for this system. The data paths for T6-T2, T7-T4 and T8-T5 are independent. Remaining pairs are also independent. Thus we could use one slot for every group (TDMA round will be includes two slots). But in case of the transmission time for pairs includes to one slot is essentially differ this distribution is not rational. We can divide transmission for every node pair to some slots for alignment of transmission time for every pair in one slot. But in this case the big number of slots results to bid time will be lost because of inter slots intervals. Because of these problems the global slots are not rational for non symmetrical systems.

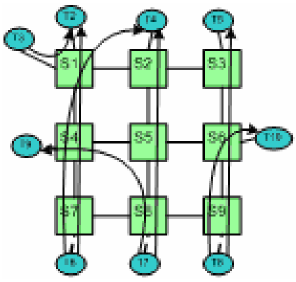


Figure 3 - example of system based on 2D-grid

4 REFERENCES

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