A Comparative Study of Synchronous and Non-Synchronous Transmission Algorithms on A Replicated Token Bus Network.

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Abstract: Increased reliability requirement in the implementation of a network is commonly met with the application of the redundancy. However, management of redundancy results in performance degradation; therefore, a designer must carefully address all critical design choices to minimize the performance loss. In a replicated token bus network, one of the major issues to address is the management of multiple tokens. Depending on the type of algorithm implemented, the performance of the network may be greatly affected. In this paper, two token management algorithms are proposed; Synchronous and Non-Synchronous transmission. Comparisons of the two algorithms are achieved through the studies in the speed performance parameter and the maximum buffer capacities required, along with the level of the design complexities involved in the development of each of the algorithms.

PERFORMANCE COMPARISON

1.1 Speed In a single channel token bus as shown in Figure 3.1, the speed at which the data is transmitted in the network is influenced by several parameters. The contributions of all the parameters results in the overall delay value, T. The parameters recognized to be significant contributors are identified as 1) Source BIU Delay (S), 2) Transmission line delay (T), 3) Destination BIU delay (D).

The source delay, S, represents the delay of the data packet preparation for transmission. This includes the time from when the BIU acknowledges the host-data placed in the transmit buffer to the time when the last bit is sent-out to the bus link is represented by S. This includes processes such as tagging the header and checksum along with converting data to serial format.

The second factor, T, is due to the propagation delay of the transmission over the bus link. The transmission over the bus link is considerable and fiber optic cables are often implemented over the standard electrical cables to increase the speed of transmission; however, as discussed in the previous chapter, even at the speed of light the delay must be calculated as a contributing factor of the delay.

The last parameter is due to reversing of the processes in the source BIU delay discussed as the first contributing factor. When the data packet is received by the destination node, serial to parallel conversion takes place, followed by the ownership verification. Thus a Tj which is the total delay between any source and destination node, is given as the sum of Sj, Ti and Dj.

To determine the speed of a network, both the token transmissions and message transmissions must be accounted. The token transmission is easily kept tracked since it must trace Ti for each path and the token length is fixed. However, message destination may differ for every message, resulting in an unpredictable combinations of S, T, and D at each transmission. We can define the total transmission time within the network as follows.

\[ T_{total} = \sum_{i} S_i + \sum_{j} T_j \]  

where \( i \) = token identification number  
\( j \) = message identification number

In a synchronous dual redundant system, all tokens being rotated in the network, one for each channel, must be passed between the two stations within some given period of time. Tokens and messages transmitted are synchronized since the time skews take place only within the adjacent stations. This is achieved by waiting for the slower channel in each path. It is easily concluded from the algorithm that the determining factor of the transmission time is the slower of the two corresponding T. Therefore, the time of transmission for the dual channel implemented under synchronous algorithm can be expressed as

\[ T_{total, sync} = \sum_{i} \max(T_{Ai}, T_{Bi}) + \sum_{j} \max(T_{Aj}, T_{Bj}) \]  

where \( A \) = Channel A  
\( B \) = Channel B  
\( i \) = token identification number  
\( j \) = message identification number

For non-synchronous dual redundant network, tokens are passed to the next station independent of the other bus token. Unlike the synchronous scheme therefore, time
skew is not bounded within each path, rather it is additive. The model of non-synchronous transmission network is identical to the model of multiple single channels operating freely except in the case of message arrival. Messages from all channels must be received to have a complete transmission. This does not affect the speed performance since tokens are not held at a station until the arrivals of the other corresponding pair. It does, however, require a matching mechanism at the receiving end since many messages may have accumulated and the node must recognize the corresponding pair of messages. The transmission delay calculations of the non-synchronous transmission network is, therefore, determined by overall transmission delay of the slower channel and it is represented by the equation 1.3.

\[ T_{\text{total, asyn}} = \max \left( \sum \max(T_{Ai} + \Sigma T_{Aj}), \right) \]

\[ (\Sigma T_{Bi} + \Sigma T_{Bj}) \]

Eq(1.3)

In contrast to the synchronous transmission where the speed is determined by each path delay between adjacent stations as shown in the equation 1.2, the speed of the transmission in the non-synchronous scheme is determined by the overall transmission delay of the channel.

There are two cases which must be considered in the speed calculations. The first of which is the case where each path of one channel is always greater than the other corresponding path. In this case, the token transmission delay expression is expanded to obtain

\[ \sum \max(T_{Ai} - T_{Bi}) = T_{A1} + T_{A2} + T_{A3} + ... \]

And, expansion of the message transmission delay term is shown as

\[ \sum \max(T_{Aj} - T_{Bj}) = T_{Ax} + T_{Ay} + T_{Az} + ... \]

Therefore, the total delay is obtained by adding the above two equations as follows.

\[ T_{\text{total, synch}} = T_{A1} + T_{A2} + T_{A3} + ... \]

\[ + T_{Ax} + T_{Ay} + T_{Az} + ... \]

Eq(1.2.1)

Similarly, for the same example, non-synchronous equation given in equation 1.3 is expanded to find the total delay as follows.

The token transmission expression is

\[ (\Sigma T_{Ai} + \Sigma T_{Aj}) = T_{A1} + T_{A2} + T_{A3} + ... \]

\[ + T_{Ax} + T_{Ay} + T_{Az} + ... \]

And, the expansion of the message transmission delay expression is

\[ (\Sigma T_{Bi} + \Sigma T_{Bj}) = T_{B1} + T_{B2} + T_{B3} + ... \]

\[ + T_{Bx} + T_{By} + T_{Bz} + ... \]

Thus

\[ T_{\text{total, asyn}} = \max \left( (T_{A1} + T_{A2} + T_{A3} + ... \right) \]

\[ (T_{B1} + T_{B2} + T_{B3} + ... \]

\[ + T_{Bx} + T_{By} + T_{Bz} + ... \) \]

Eq(1.3.1)

Since every path delays of channel A is greater than the channel B, the equation 1.3.1 is reduced to equation 1.3.2.

\[ T_{\text{total, asyn}} = (T_{A1} + T_{A2} + T_{A3} + ... \]

\[ + T_{Ax} + T_{Ay} + T_{Az} + ... \]

Eq(1.3.2)

As expected, equation 1.2.1 and equation 1.3.2 are identical. The \( T_{\text{total}} \) in both of the algorithms are equal therefore, the same performance is expected. Obviously when the special condition such as the one shown above arises, the summation of each slower paths equal to the total \( T \) of the slower channel.

For the second case, random transmission delays are assigned for each paths and the speed of the transmission is analyzed by calculating the total \( T \) in the network. As illustrated, the non-synchronous and synchronous transmission delays are expanded to equations 1.2.1 and 1.3.1. The maximum terms in the above equations are chosen depending on the magnitude of the \( T_s \). However, it is easily seen that neither of these terms are greater than the value represented in the synchronous expression for any given combination of transmission delays. This is due to the nature of synchronous transmission algorithm where its transmission delay, represented by the equation 1.2.1, is the combination of the longer transmission delays in each of the corresponding paths. Thus equation 1.3.1 is always less than equation 1.2.1.

1.2 Buffer Capacity There are two types of buffers which must be considered in a BIU as shown in Figure 1 - Transmit queue and the receiver queue. Transmit queue is the buffer which provides the temporary storage of messages from the host waiting to be passed in the network link, whereas receiver buffer in the BIU has exactly the opposite role.

1.2.1 Transmit Buffer Size The comparative analysis is under the assumption that the synchronous and non-synchronous transmission redundant networks are identical except for the token/message passing algorithms implemented on the network. This assumption, in turn, leads that all parameters such as message generation rate, \( \bar{A}_T \), message processing rate, \( \mu_T \), associated with the corresponding hosts in the two networks are the same. However, message departure rate, \( \mu_R \), and the message arrival rate \( \bar{A}_R \) are not the same since their values are proportional to the transmission speed of the network. The transmission speed is therefore compared with the relative values of the \( \mu_T \) and the \( \bar{A}_R \) alone. In general, a slower network will require a larger Transmit buffer size since the number of the messages dequeued in the Transmit queue is lower in the slower token passing.
network. A faster network requires a larger receiver buffer because of the higher enqueuing rate. On this basis, we may conclude simply that the Transmit buffer must be defined to be larger in the synchronous network and the receiver buffer is larger in the non-synchronous network. An exception is in the special condition where all path delays in one channel is greater than the corresponding paths in the other channel as it is discussed in the section 1.1. The worst case buffer size under this condition is obviously the same in both of the networks.

1.2.2 Receive Buffer Size Unlike the Transmit buffer size analysis, the receiver buffer size determination is heavily dependent on the message service discipline implemented in the hosts. Receiver buffer collects the messages from the network link then stores them until the host is ready to service the data. The service by the host can be selective on the messages in the buffer which plays a major role in determining buffer sizes. However, it does not influence the Transmit buffer size since the token bus has no capability of discriminating one message from the other.

Again, there are many ways in which the arriving messages are selectively serviced and this is completely defined by the requirements of the host. In this study, we will consider an example of service discipline where messages in the receiver buffer will be selectively serviced. In detail, if the selected message to be serviced does not reside in the buffer, then no other message is serviced until that message arrives and serviced. The receiver buffer capacity analysis under non-selective service discipline followed by the comparative study under the selective service discipline just described will be conducted on both of the networks.

1.2.2.1 Synchronous Transmission Receive Buffer Size In a redundant synchronous token passing bus, data in all channels are passed between the adjacent hosts in coordination with the slowest channel. This type of transfers result in orderly collection of messages in the receiver buffer, that is, corresponding messages from all channels are received in the same order. If the messages are non-selective, this only requires a small unit of reserved buffer in each node. This is, of course, under the assumption that the system is stable, where arrival rate is smaller than the servicing rate.

In a graphical representation, the small buffer capacity required is easily illustrated as shown in Figure 2. As the messages arrive at the queue, $E(t)$ which represents the cumulative arrivals is increased and it is ultimately serviced by the host increasing the cumulative departures, $B(t)$. In Figure 2, $t_{A1}$ represent the arrival times of the channel A messages and the $t_{B1}$ represents the arrival times of the channel B messages. At time $t_{B1}$, both channels' messages have arrived at the queue and increases the $E(t)$ by one, then, host processes the message at $t_1$ leaving both of the receiver buffers empty. This process continues for all the other $t_i$ such that largest buffer size can be easily identified by determining the largest $L$ in the graph.

Mathematically, the difference between $E(t)$ and the $B(t)$ represents queue length required at a given time $t$ as shown in the equation 2.

$$L(t) = max\{E_A(t), E_B(t)\} - B(t) \quad Eq(2)$$

Therefore, the maximum buffer size requirement is represented in the following equation.

$$L(t) = max\{ max\{E_A(t), E_B(t)\} - B(t)\} \quad Eq(3)$$

Under the same network in consideration, the host may be selective to processing the messages received in the buffer. This is the case where a host waits for the targeted message to arrive at the BIU, leaving the messages currently residing in the receiver buffer to wait. The worst case scenario of selective services in the synchronous scheme arises when the tokens have just passed the station with the vital message. This forces the tokens to make a complete rotation in the network transmitting all the pending messages in the process, before it can return to the station with the vital message to be transmitted. Concurrently, all messages received in the receiver buffer must be stored until the selected message arrives, requiring larger buffer space than in the non-selective case.

This is illustrated graphically in Figure 3. The patterns of $E(t)$ which is the arrival accumulations remained the same, however, $B(t)$ is changed due to the targeted message waiting time. Several messages have arrived at the receiving buffer at times $t_{A1}, t_{A2}, t_{A3}, t_{B1}, t_{B2},$ and $t_{B3}$. At $t_1$ selected messages arrived at the receiver buffer allowing the host to process the messages in the buffer, however, the messages arrived between $t_{A1}$ and $t_{B3}$ are stored in the buffer filling the buffer by $L$. There are no changes of arrival rates to the receiver buffer in both the selective and non-selective cases, which results in the identical $L$, the arrival rate. However, departing rates have changed due to the changes in the host response time. Although the inherent processing rate of the host remains the same the overall processing rate is decreased due to the service discipline applied.

The comparison of the buffer sizes in the synchronous scheme is, therefore, shown to be larger in the selective service discipline over the network implemented with non-selective service discipline.

1.2.2.2 Non-Synchronous Transmission Receive Buffer Size In the non-selective service, unlike the synchronous algorithm, respective token positions cannot be predicted. The consequence of which is that all corresponding messages are not guaranteed to
arrive within the time skew and the order of messages arriving at each of its respective channels are not the same. The order of messages received at each channel heavily depends on the token positions when messages are pending for transmission in the network. Thus, the worst case buffer size in non-selective service arises when the tokens are separated within the network such that maximum number of messages are passed by one token before any one token is possessed at the original position of the other token. However, if the assumption that all Ts are identical is removed, the buffer size changes drastically. Consider a network where the condition stated in the equation 4 holds true and the tokens are positioned at node 1 in channel A and at node 2 of channel B. This condition implies that all messages transmitted by the token in channel B must be buffered until the token in channel A reaches the station 2.

\[ T_{A1} \geq \sum T_{Bi} \] (Eq 4)

This condition can be easily extended to more than one path within a channel to achieve a worse conditions. It is easily seen that under the condition of equation 4, the buffer sizes can be very large. However, it is highly improbable that such condition may hold in any systems. In order to satisfy the condition in equation 4, the message clock skew and the propagation delay of a path must be as long as a token to rotate a channel completely. Even with intentional design practice, this kind of magnitude of path delay is difficult to achieve. In general, it is not unreasonable to assume that the channel delays are fairly matched. Most of the different routing of the connections cover approximately the equivalent distances and the clock skews are not drastically noticeable. Even when a path retains much larger delay than the corresponding path in the other channel, this is most likely to be counter balanced by the lesser magnitude of the delay in other paths in the same channel.

Under the assumption that all path delays are similar in magnitudes, the maximum buffer size of the non-synchronous algorithm with no service discipline is about half the total number of stations in the network. This is definitely much larger than the non-selective service in synchronous token passing algorithm and smaller than the selective synchronous scheme.

In the selective service of asynchronous algorithm, the time delay parameter plays the same role as it is stated in the non-selective service discussion. But, again, under the same assumption that all Ts are fairly competitive values, the buffer size is exactly the same as the buffer size determined in the selective service of synchronous token passing network.

1.3 Other Design Considerations In assessing the hardware requirements for both non-synchronous and synchronous algorithms, it is obvious that large differences are not observed, except in the case where the condition given in the equation 1.7 holds. If more than one path in the same channel satisfies the condition, considerable overhead in the buffer requirement is the most distinguishing factor in the non-synchronous transmitting network.

Complexity of the synchronous transmission network design is most apparent in the requirement of node to node communications. To realize synchronous transmission algorithm, status of messages or tokens received in each node, both from the bus and the host, must be communicated with its corresponding nodes. The consequences of this is the connections between the nodes to support its status checking process. When a token or a message is received from the bus, received information(flag) must be relayed to the corresponding node so that the stations know when all the tokens or messages are received. However, this is not true for non-synchronous algorithm since all channels are independently operated.

Message management, on the other hand, is a major drawback in the non-synchronous transmission network. Messages may be received in different order in each corresponding channels. Immediately, there is a need for a sophisticated message matching algorithm. This must include a way of identifying and distinguishing each message and comparing that to the messages in the other channel for an identical match.

The problem of contention also arises when all the corresponding nodes received a message at the same time. A non-trivial contention resolver, either in software or in hardware, must be incorporated to decide which node searches for an identical message in other nodes first. This process can easily be the speed determining factor if the message manager is inefficient. Once the messages are received, the comparison operation occurs. Some form of information should be included in each messages to distinguish them. This may further increase the length of a message affecting the speed performance.

2. BEHAVIORAL LEVEL SIMULATION
2.1 Simulation Model In this section two models of Linear Token Bus, one for each algorithm, built in a hardware simulation language, ISP, is presented for the comparison study. The model consists of dual redundant Token Bus with multiple hosts connected in each channel as shown in Figure 4. The rate at which the messages are generated at each host is generated randomly with uniform distribution and this is depicted by "Gen Rate". Similarly, service rate determines the rate which the messages in the receiver queue is serviced by the host. Both the destination node and the Delay Generators each residing in their respective bus interface units mimic propagation delays, clock skews, and the message lengths.
The service and the generation of messages is identical for both nodes in each station.

Transmission speed over a certain period time along with the transmit buffer size are obtained to analyze the two algorithms. The simulation time period is set such that both of the networks reach the equilibrium where no erroneous result occur due to the unpredictable initialization. The basic structure of local area bus networks for three, ten, and twenty-five hosts are simulated. As noted before, numbers presented in this section are purely a comparative results and only the relative values within a given number of nodes are valid. The units of speed is defined by the clock cycle given in the model network and the buffer size is obtained under the assumption that one message is considered to occupy one buffer unit. Also each station is assumed to send only one message of a fixed length per revolution when there are more than one messages in the transmit buffer.

2.2 Speed Performance The total number of messages completed the transmission within the given simulation period is shown in Figure 5. The results conform to the discussion of speed analysis presented in section 1. In general, non-synchronous algorithm show more number of messages completing the transmission for lower delays than the synchronous algorithms. But as the message generation rate decreases, the difference disappears. At lower generation delays, the number of messages generated are faster than the speed at which the bus can transmit them, thus allowing the speed of the bus to be the determining factor in the system. However, as the generation rate decreases, the speed of the bus becomes faster than the rate at which the messages are generated by the hosts thus the speed determining factor becomes the message generation rate. Since the messages are generated at the same rate in both of the algorithms, the two curves for synchronous and non-synchronous schemes are identical as shown in the higher ranges of generation delays.

2.3 Average, Maximum, and Minimum Transmission Time Another important parameter is the average transmission time of each message. This is shown in Figure 6. The average transmission times collected correlate well with the number of messages completed the transmission. Again, Figure 6 support the faster speed of transmission for the non-synchronous algorithm in the same lower ranges of generation delays.

Similarly, maximum and minimum transmission delays experienced by any completed message are shown in figures 7 and 8. Although faster speed of the non-synchronous algorithm is apparent in the maximum time curves, minimum curves do not support the same conclusion. Surprisingly, larger minimum values are shown for the non-synchronous algorithm in the ten and twenty-five station networks and a reversed result in the three station network.

2.4 Buffer Size The buffer capacity requirement comparison results are heavily dependent on the results of speed performance of the bus network since the speed of the bus determines the service rate for transmit buffer and the message generation rate for the receiver buffer. Again, three, ten and twenty-five stations connected in each channel and the dual redundant network is simulated for both synchronous and non-synchronous algorithms. The message generation rate of the hosts varies as shown in the x-axis of Figure 9 and the transmit buffer sizes are tabulated.

As expected, transmit buffer sizes are smaller for non-synchronous algorithm and when the generation rate decreases, the transmit buffer sizes are identical in both algorithms. The region where both graphs overlap is where the speed of the bus is faster than the speed of message generation by the hosts. Another words, dequeuing process is faster than the queueing process resulting in a very small buffer sizes. In this region, the buffer is empty most of the time until a message is generated by the host then it is immediately dequeued. As the message generation rate is increased, the enqueueing of the buffer becomes faster than the transmission speed, consequence of which is the larger buffer sizes. However, the dequeuing rate of the non-synchronous algorithm is faster due to its faster speed performance which results in a smaller buffer sizes. Similarly, receiver buffer sizes are analyzed in the same manner except the conditions are reversed. We can easily see that the receiver buffer sizes are larger in the non-synchronous algorithms due to its faster enqueueing rate.

References


Fig 1 Token Bus Network

Figure 2 Non-Selective, Synchronous Network Buffer Size

Figure 3 Selective, Synchronous Network Buffer Size

Figure 4 Simulation Model of Token Bus
Figure 5 Total Number of Messages Completed Transmission

Figure 6 Average Transmission Time.

Figure 7 Maximum Transmission Time

Figure 8 Minimum Transmission Time.

Figure 9 Transmit Buffer Size Comparison

Figure 10 Receive Buffer Size Comparison.