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New Proposed Contention Avoidance Scheme for Distributed Real-Time Systems

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Abstract: **One method to handle collisions in a contention based distributed system is to optimize collision detection and subsequent recovery. An alternative method to handle collisions in a contention based system is to attempt to avoid them. Some systems may utilize a strict scheduling guideline to identify who may use which resources when. Other systems may have the senders listen to the channel immediately prior to transmitting and determine suitable times to transmit. A primary challenge in Distributed Real-Time Systems applications is how to carry out data given source-to-sink, end-to-end deadlines when the communication resources are scarce. A new scheme resolves collisions and tries to reduce the number of potential collision events. In this paper, we develop New Avoiding Contention Scheme that delays data packet transmission nonlinearly during forwarding for a duration that correlates with their remaining deadline and distance to the destination, and avoiding the contention in bursty traffic by using multi-path routing**

Keywords: **Bursty traffic, Contention avoidance, Real-Time scheme, Distributed systems, Multi-path Routing.**

1. INTRODUCTION

Distributed Real-Time Systems typically operate under load that is depending on the application and then suddenly become active in response to a detected or monitored event. Depending on the application this can result in the generation of large, sudden, and correlated impulses of data that must be delivered to a small number of sinks without significantly disrupting the performance (i.e., fidelity) of the sensing application. Although Distributed Real-Time Systems may spend only a small fraction of time dealing with impulses, it is during this time that the information it delivers is of greatest importance. The transport of event impulses is likely to lead to varying degrees of congestion in distributed systems. The contention directly affects the system performance. Indeed each burst dropped means a wasted bandwidth, increased delivery delay and decreased throughput. This means that the global efficiency and performance of the global system depends on the loss rate, and hence the performance falls as the load gets higher

The performance is affected by both the routing scheme and the packet scheduling algorithm. Consider that in the absence of contention, the delay of a packet is proportional to the number of hops on the path from the distributed to the sink, where the selected path is determined by the routing scheme. In the presence of contention, additional delays are incurred as the packets are queued behind other packets. In response to this, future contention avoidance mechanisms for distributed systems must be capable of balancing the offered load, while attempting to maintain acceptable fidelity (i.e., rate of events) of the delivered signal at the sink during periods of transient and more persistent congestion. A number of distinct congestion scenarios are likely to arise. First, densely deployed distributed generating impulse data events will create persistent hotspots proportional to the impulse rate beginning at a location very close to the sources (e.g., within one or two hops). In this scenario, localized, fast time scale mechanisms capable of providing backpressure from the points of congestion back to the sources would be effective. Second, sparsely deployed distributed generating low data rate events will create transient hotspots potentially anywhere in the distributed field but likely farther from the sources, toward the sink. In this case, fast time scale resolution of localized hotspots using a combination of localized back-pressure (between nodes identified in a hotspot region) and packet dropping techniques would be more effective. Because

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of the transient nature of congestion, source nodes may not be involved in the backpressure. Third, sparsely deployed distributed generating high data-rate events will create both transient and persistent hotspots distributed throughout the distributed field.

In this paper, we develop New Avoiding Contention Scheme that offers significant advantages over existing wireless real-time data communication schemes. It reduces contentions to improve real-time performance by providing the flexibility of the nonlinear slack allocation. Contention Avoidance Scheme delays data packet transmission nonlinearly during forwarding for a duration that correlates with their remaining deadline and distance to the destination. Also we implement the Contention Avoidance Scheme algorithm with a multi-path routing scheme that is intended to provide a reliable transmission environment for data packet delivery and improve real-time performance. The braided multi-path routing which we use in our scheme, choose the best path and shortest one without exceed the delayed time makes more efficient used for the bandwidth and so decrease the packet miss ratio, drop ratio and overall delay which we consider them our accuracy measure in distributed systems. This scheme efficiently utilizes the available memory resources of distributed nodes. It also has a significant impact on the success of wireless real-time data communication data communication and avoids contention. Simulation experiments show that the used scheme outperforms traditional schemes by establishing a reliable path from the source to the sink by distributing the traffic load more evenly in the system. Moreover, delaying the data packets before reaching the sink also helps the data aggregation/fusion and therefore energy efficiency. The primary contribution of our work is more effective communication; and avoiding the contention in bursty traffic by using braided multi-path routing. The reminder of paper is structures as follows: related works are introduced in section2. The framework of the new scheme is illustrated in section 3. In section 4, the effect of increasing the number of created sub-packets corresponds to the number of available paths is explained. Simulation results and conclusion are discussed in sections 5 and 6, respectively.

2. RELATED WORKS

Clearly, the ability to meet real-time deadlines in the presence of contention is related to controlling the load presented to the system. In terms of system resources, this is the problem of congestion control. Exploring the intersection of contention avoidance and real-time scheduling is an interesting topic of future research. One of the proposed solutions for real-time system [1] prioritizes packet transmission at the MAC layer according to the deadline and distance from the sink. These works have several limitations: (1) Packets generated by different distributed systems at the same time (e.g., in response to a detected event), can lead to high contention rates. Jittering such packets can help reduce this hot-spotting; (2) MAC level solutions cannot account for the queuing delay in the routing layer (which occurs above the MAC layer); these delays can have a significant impact on end-to-end delay especially under high load; and (3) MAC level solutions require reengineering of the distributed radio hardware and firmware, making deployment difficult and potentially causing interoperability problems with earlier hardware that supports different MAC schemes. To meet QoS requirements such as bounded delay or guaranteed delivery, contention is a key. Several methods have been proposed in the literature to decrease the loss rate. Some of these techniques could be implemented in software, such as deflection [15] routing and segmented bursts [1], while the others require specific hardware, such as burst buffering [16,7] and wavelength converters [17,7]. These techniques may reduce the contention, but they all remain sensitive to the traffic load. Indeed, it is clear that even in ideal systems, where the switches use a number of buffers and can perform wavelength conversion, contention still occurs when the load gets higher. This means that the best way to deal with the contention problem is to control the traffic and keep the load in an optimal range as long as possible. Furthermore, in OBS, the load control could be done only by the edge nodes since they have more intelligence and they have physical resources such as buffers and can handle both electronic and optical information. Unfortunately, they do not have enough information to adjust their throughput accordingly. No global state is available and the edge nodes are sending data bursts without any coordination. In the following section we will focus on an algorithm that controls the load and achieves fairness among all the system edges. They will be able to share the available system capacity while keeping the dropping probability at a low level. In the same time, whenever a burst is dropped the source node will be notified in order to retransmit the lost burst and hence guarantee delivery, thus avoiding the long retransmission delay of TCP. Since the scheduling needs to consider the queuing delay in the routing layer which is above the MAC layer, the impact of the routing schemes used must be carefully examined. The effect of the routing scheme on the real-time scheduling success is not sufficiently understood. Some existing solutions [2] [3] [4] for routing in real-time traffic context provide non-deterministic routing as an extension of stateless geographic-based routing schemes. More specifically, these approaches use the best next hop with respect to the traffic/congestion

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situations, not only the geographic proximity as per the greedy Geographical Forwarding scheme. Furthermore, when using a longer path in terms of number of hops, increased contention for the medium results as more transmissions are needed to forward a packet. So we propose new scheduling scheme that schedules the data packets exponentially and uses braided multi-path routing. This scheme overcomes those shortcomings.

The performance of Distributed Real-Time Systems applications is affected by both the packet scheduling algorithm and routing scheme. The effectiveness of this communication can be measured in terms of the deadline miss ratio. Existing solutions for real-time data communication in distributed systems prioritize packets at the MAC layer according to their deadlines and distances to the sink. These solutions have several limitations including: when traffic is bursty, high contention may result increasing transmission and queuing delays; and MAC level solutions can not account for the queuing delay in the routing layer. In section 3, we introduce the framework of our scheme in detail.

3. CONTENTION AVOIDANCE SCHEME FRAMEWORK

In this work we propose an approach to keep the load in the acceptable area and make sure that all the edge nodes contribute fairly to this load. The basic idea of this technique is that the edges receive statistical reports (concerning the loss inside the system) that help to calculate the system performance, and hence determine from the loss-load relationship the current traffic load. Therefore by learning from this statistical data, each node increases or reduces its throughput. These statistical reports could be used by the edge nodes to monitor and control the whole system. A statistics distributor protocol could be implemented, as an extension in a control plan, using the same wavelength used to carry the burst headers. This approach aims to control the traffic and keeps it out of congestion area. Similar approaches to congestion avoidance [18,19,20], have been considered in the literature for TCP/IP packet switched systems and asynchronous transfer mode (ATM). Congestion control is a recovery mechanism that helps a system to get out of a congestion state, whereas congestion avoidance scheme allows a system to operate in a safe area. Many solutions have been proposed in the literature to practically control congestion, the most popular are window flow-control and rate flow control. In the windows flow-control scheme [20] (used by TCP), the destination specifies a limit on the number of packet that could be sent by the source. This limit is increased and decreased by the destination dynamically during the whole session to regulate a data flow. In rate flow-control scheme, the destination or the system may ask a source to decrease its rate. Besides that, ATM uses other sophisticated mechanisms to control congestion including traffic shaping and admission control as well as resource reservation. Regardless of the efficiency of these mechanisms, all of them perform congestion control in the electrical level where some resources are available especially buffers and storage spaces that contribute actively in the control process. The idea of optical congestion control is to push some of these functions to the optical domain where a new constraints (buffer-less system) and new challenges rise. Performing congestion avoidance and congestion control in the optical domain increases the performance (in terms of loss rate) of optical burst switching and improves resource utilization.

Contention Avoidance Scheme is the primary contribution of this paper. Contention Avoidance Scheme delays data packet transmission during forwarding for a duration that correlates with their remaining deadline and distance to the destination. Intuitively, this helps in heavy-traffic communication environment by making sure that priority inversion does not occur. Inversion occurs due to a node with only low priority packets sending and preventing a node with high priority packets from doing so. In summary, the following information is needed to schedule packets in Contention Avoidance Scheme: End-to-end deadline information: this information is provided by the application in the data packet as required by any real-time data communication application. For those applications where the header of data packet does not include this information, an alternative way for Contention Avoidance Scheme to obtain the end-to-end deadline information is needed. Also, End-to-end distance information: this information is obtained from the routing scheme. In geographic routing, Euclidian distance measured as the distance from the current node to the destination. It can be used as the distance metric. End-to-end distance which can be measured either in numbers of hops like in Shortest Path Routing or by the difference between the average length of an alternate path and the length of the primary path as in Braid multi-path routing. Contention Avoidance Scheme is possible to allocate the available slack time non-uniformly among the intermediate hops along the path to the sink. For example, we may desire to provide the packets with additional time as it gets closer to the sink. The intuition is that in a gathering application, the contention is higher as the packet moves closer to the sink. More generally, we may want to allocate the slack time proportionately to the degree of contention along the path. We explore an *Exponential increasing delaying* policy with multi-path routing to break down the available time. We used multi-path routing that choose the best path in the case of congestion and apply heuristic scheme that attempts to pick the lowest latency path in Distributed Real-Time Systems without contention:

Delay is used to decide how long a data packet can be queued locally. If the Delay is zero, the packet is forwarded at once. A single priority queue is used to queue all incoming data packets. In fact the Delay is the priority of the packets.

The Contention Avoidance Scheme scheduler resides above (or within) the routing layer. The Contention Avoidance Scheme scheduler and the MAC layer scheme are not aware of each other. It uses routing level information such as the end-to-end distance in making its scheduling decisions.

Existing real-time data communication work have developed packet scheduling schemes cannot completely support real-time data communication requirements. In our work, we develop new scheme to reduce contentions and improve real-time performance and demonstrate that the multi-path discipline has a significant impact on the success of real-time data communication in wireless communication systems and avoid contention as we see in the next section. For any real-time applications based on Contention Avoidance Scheme, the end-to-end real-time deadline is assumed to be included on the data packet itself. Since Contention Avoidance Scheme is mainly designed for soft real-time applications, Contention Avoidance Scheme immediately forwards such packets without any delay even if the packet misses the deadline. A single priority queue for packet forwarding based on the computed target transmission time is used by the Contention Avoidance Scheme scheduler. Transmission is accomplished via a timer that is set to the target transmission time of the head of the queue. When the queue is full, the Contention Avoidance Scheme scheduler selects the packet at the head of the queue to immediately forward it instead of dropping any packet in the queue. MAC layer prioritization is not needed by the Contention Avoidance Scheme design since the packets are sent when their local deadline is reached. Not requiring changes to the MAC layer is a desirable feature of Contention Avoidance Scheme. The output of Contention Avoidance Scheme scheduler is the queuing delay. Queuing delay is used by the routing scheme to decide how long to delay an incoming data packet before attempting to forward it (by passing it to the MAC layer). The queuing delay computes the duration that is the packet used to be queued in the Distributed Real-Time Systems layer before it is handed to the MAC layer for transmission. This delay can be directly controlled by the Contention Avoidance Scheme scheduler as we illustrate in section 3.1.

3.1 Recourses Management:

To manage limited recourses such as bandwidth, Priority queuing can be used on a transmission line from a system router. In the event of outgoing traffic queuing due to insufficient bandwidth, all other queues can be halted to send the traffic from the highest priority queue upon arrival. This ensures that the prioritized traffic (such as real-time traffic) is forwarded with the least delay and the least likelihood of being rejected due to a queue reaching its maximum capacity. All other traffic can be handled when the highest priority queue is empty. Another approach used is to send disproportionately more traffic from higher priority queues. Many modern schemes for wireless Contention Avoidance Scheme systems also include the concept of Priority Queues at the MAC sub-layer to ensure that high-priority applications experience lower latency than other applications which can be served with Best effort service. Examples include IEEE 802.11e (an amendment to IEEE 802.11 which provides Quality of Service). A single priority queue is used in the routing layer for forwarding packets. A single priority queue can better track the priority of data packets than the approach of several FIFO queues with different priority levels. The processing time of queuing operations is much shorter than the queuing delay, so this overhead does not affect the performance much as it does in Real-Time scheduling design. The priority of each data packet is the queuing delay decided by the Contention Avoidance Scheme scheduler. This priority does differentiate not only the requested delay of each data packet, but also their possible queuing status. When the priority queue is full, the data packet at the head of the queue is forwarded at once no matter how long it needs to be queued due the Contention Avoidance Scheme scheduling. As we can see, this is a best effort forwarding policy which may cause the most urgent data packet to be dropped. However, the benefit of this solution is that the packet at the queue head has a higher local priority and is less likely to be dropped by lower layer communication later. Real time multi-path finds a least cost and energy efficient path that meets certain end-to-end delay during the connection. The link cost used is a function that captures the nodes' energy reserve, transmission energy, error rate and other communication parameters. In order to support both best effort and real time traffic at the same time, a class-based queuing model is employed. The queuing model allows service sharing for real-time and non-real-time traffic. The scheme finds a list of least cost paths and picks a path from that list which meets the end-to-end delay requirement. In section 4, we present some

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considerations on how to predict the number of paths that will successfully deliver a packet among the multiple disjoint paths obtained from the route discovery process.

4. DATA PACKETS SPLITTING

The increase of the probability for the successful delivery comes at the trade-off of added redundancy. The entire data package to be sent from the source to the destination over the available k disjoint paths will be split up into smaller sub-packets of equal size. The number of created sub-packets corresponds to the number of available paths. Only a smaller number of these sub-packets will then be needed at the destination to reconstruct the original packet. There exist several fast and simple (i.e. linear) forward error correcting codes (or erasure codes) that allow the reconstruction of an original packet that has been split up and of which not all parts arrive at the destination. In the following, we will focus on approximating a value of successful paths. This value will then be used to determine the amount of redundancy to be added for the split packet transmission.

The total number of sub-packets is a function dependent on the multi-path degree and on the failing probabilities of the available paths. As these values change according to the positions of the source and the destination in the system, each source must be able to decide on the parameters for the error correcting codes before the transmission of the actual data sub-packets.

We want to send a data packet from a source to a destination and the process of route construction is finished, resulting in k different paths that are to be used. Each path has some rate that corresponds to the probability of successfully delivering a packet to the destination. This setting corresponds to a repeated experiment, the sub-run corresponding to the packet transmission along the ith path. Note that we consider node-disjoint paths and therefore can assume these experiments to be independent of each other. Obviously, each combination of the multi-path degree k and different probabilities will yield a different normal distribution. To overcome this problem, we transform to the standard normal distribution. Now, consider a given bound α for the desired probability of being able to reconstruct the original packet at the destination after being sent along the different paths. In terms of the input for the decision algorithm, the value for Ek is given by the following expression which gives the number of successfully delivering paths with the overall success probability of α.

5. SIMULATION RESULTS AND ANALYSIS

In order to evaluate the performance of the proposed congestion avoidance scheme, we performed a number of simulations on a mesh system. In this simulation we consider a NSFNET topology with 14 nodes.

In a Contention Avoidance Scheme system, where node density is high and bandwidth is scarce, traffic hot spots are easily created. In turn, such hot spots may interfere with real-time guarantees of critical traffic in the system. In our work, we apply a combined Contention Avoidance Scheme and MAC layer congestion control scheme to alleviate this problem. To test the congestion avoidance capabilities, each node publishes packets alternately at the pre-set data rate for 5 seconds then stops publishing for the second 5. Figure 1; show a comparison of the loss ratios result of real time system with and without using Contention Avoidance Scheme under the bursty traffic with end-to-end deadline from 0.1 second to 0.6 seconds.

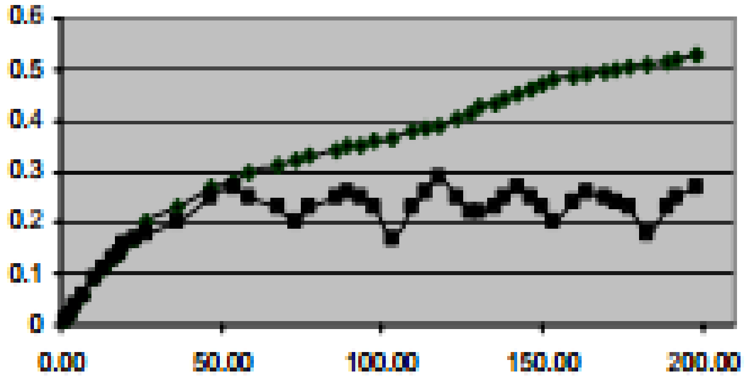

Figure1: Contention Avoidance Ratio under bursty traffic

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From the figure we can see that the miss ratio of Contention Avoidance Scheme is much lower than that of with the bursty traffic. Since Contention Avoidance Scheme uses multi-path routing which is necessary to make sure that the capacity of the Distributed Real-Time Systems does not be exceeded, hence no packets are truncated. Contention Avoidance Scheme can tolerate the traffic burst by routing some packets to free routes in the system. In addition, this scheme is necessary to optimize the lifetime of the Distributed Real-Time Systems while meeting the minimum accuracy requirements of the application. Thus, the congestion control must not only be based on the capacity of the system, but also on the accuracy level at the observer.

In figure 2, we show the effect of applying the congestion control and avoid the contention in the Distributed Real-Time Systems by decreasing the drop ratio and delivering more packets, and get small loss rate.

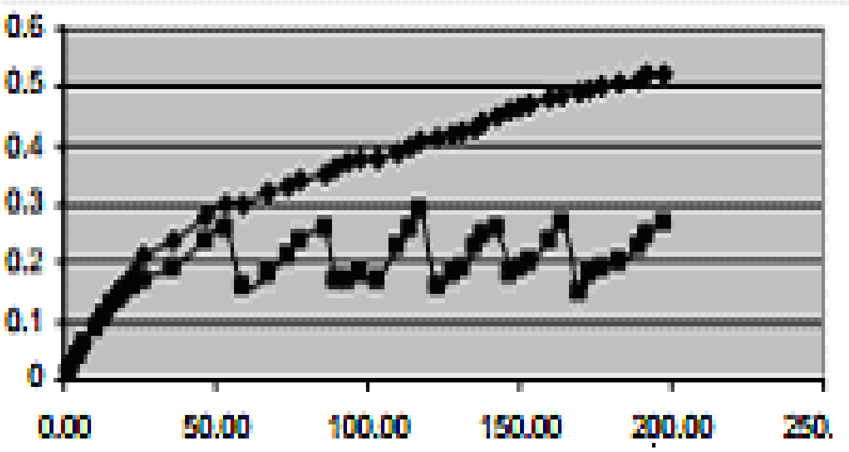

Figure2: the loss ratio

In this simulation all the nodes with traffic load beyond the critical load should return back to the critical load).

We observe that the loss is dropped sharply to the critical loss when the congestion is detected and continues to oscillate around the critical loss. Nonetheless the result is very similar to the previous one where the loss is dropped progressively to the critical loss. And both of them prove that the congestion control technique effectively controls the loss and optimizes the resource utilization.

6. CONCLUSION

In heavy traffic environments, large queuing delays may be experienced at intermediate nodes before they are forwarded to their next hop. This situation may occur at several intermediate nodes before the packet reaches its destination. Contention Avoidance Scheme delays packet transmission during forwarding for a duration that correlates with their remaining deadline and distance to the destination. Intuitively, this helps in heavy-traffic communication environment by making sure that priority inversion does not occur due to a node with only low priority packets sending and preventing a node with high priority packets from doing so.

Contention Avoidance Scheme utilizes multiple routes and distributes the data to multiple candidate neighbors to avoid contention and control congestion problem. Contention Avoidance Scheme Scheduling makes sure that the capacity of the Distributed Real-Time Systems does not be exceeded and hence no packets are truncated. It can avoid contention in the system. Further, Contention Avoidance Scheme is a routing layer solution and does not require changes to lower level schemes making it easier to deploy and independent of the underlying The Contention Avoidance Scheme focuses on scheduling packets under heavy traffic situations. We did not examine the problem of scheduling under a light load. If the traffic through the current node is not heavy and queuing time is small, real-time scheduling is not needed and in fact may harm performance. If such a situation can be detected, the Contention Avoidance Scheme can be disabled and packets forwarded normally. We noticed that the scheme efficiently utilizes the limited energy and available memory resources of Contention Avoidance Scheme nodes and also has a significant impact on the success of real-time data dissemination and avoids contention.

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