

QUALITY OF SERVICE PARAMETERS WITHIN A MIXED NETWORK FOR THE INET ENVIRONMENT

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ABSTRACT

The focus of the integrated Network Enhanced Telemetry (iNET) project is to enhance the current telemetry technology (IRIG106) and still maintain the reliability of the current technology. The Mixed Networking environment is composed of a wired network based on standard 802.11 and a modified wireless based on 802.11. Determining the viability of the networking scheme within the iNET project is critical. The QoS features such as delay and jitter are measures of performance specified by user conditions. These QoS features are measured against current legacy links. This paper will show a comparison of the three QoS levels (best effort, assured, and premium services) that the network provides and investigate QoS performance of the Mixed Network in the iNET environment. This will provide a framework for assessing the strength and weakness of the Mixed Network as well as scoping further research.

KEYWORDS

Quality of Service, Mixed Network, Adhoc, Contention, Information Theory, Shannon Channel Capacity

INTRODUCTION

The purpose of the iNET project is to create a networking framework that will allow the current IRIG (106) links, which are single one-way dedicated links, to be phased out in favor of a more network centric multiplexing approach. The goal of the iNET project is to take the test range environment from the current one-way dedicated links to a more bandwidth efficient multiplexed approach, bring the Telemetry environment to a place that the commercial environment has thrived. The technological advances of the military usually push the improvement of the commercial environment, but in terms of networking the military has been very cautious in making the conversion to network environment for a variety of security concerns. Commercial technologies are driving the development of more robust communication solutions for integrated networks.

This paper focuses on the development of a framework that can be used to ascertain the effectiveness of techniques on the overall performance of a system. The purpose of this framework is rooted in information theory and will serve to bound both the contention and QoS problems into a single workable formulation that will show their interdependence. This interdependence is a trade-off space that can be used to compare the effectiveness of many different approaches. This framework will be used to show the performance bound of the mixed network concept and provide insight into possible changes or modifications that could increase the network's performance.

CONTENTION

Contention is a measure of competition for limited network resources. In the Adhoc environment resource management is a very important task that is further complicated by the fact that there is no central controlling element to help the nodes communicate. This lack of a controlling element has its strengths and weaknesses. A great deal of research has gone into finding new and creative ways to deal with this issue [1] [2] [3]. The underlying contention issue stems from the fact that there is no getting around access limitations as shown by Choi [4] and as illustrated in figure 1.

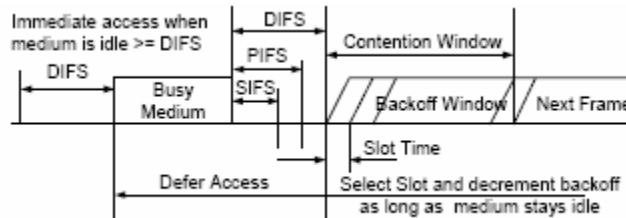


Figure 1 802.11 Channel Access

The random backoff window used to avoid collisions in the adhoc environment leads to an increase in the wait time other nodes or streams have to wait to transmit data. If you can find the wait time, you can maximize the usability of the channel.

QUALITY OF SERVICE

Quality of Service (QoS) refers to the network's ability to provide resources for real-time and non real-time applications. The implementation of QoS over an Adhoc network has been researched extensively [5] [6]. The solutions for QoS have prompted additions to the 802.11 architecture in the form of an extension 802.11e for QoS [7]. This extension requires some kind of priority system to help improve the quality of services like voice and streaming video. QoS is a process by which different flows of traffic are tagged with markers that specify different service levels. These different service policies indicate the level of priority with which the packets in the stream will be processed. These service policies allow service providers to give a conditional level of QoS in an otherwise unreliable network structure. Of course this service agreement is quite different for the standard QoS policies of wired networks in that there is no way to guarantee that there will be a source to destination path in a wireless adhoc network.

MIXED NETWORK MODEL

The Mixed Network model is hybrid of the standard 802.11 network with a adhoc extension added to provide connectivity to users outside of the access point. Figure 2 is an example of how the network might look.

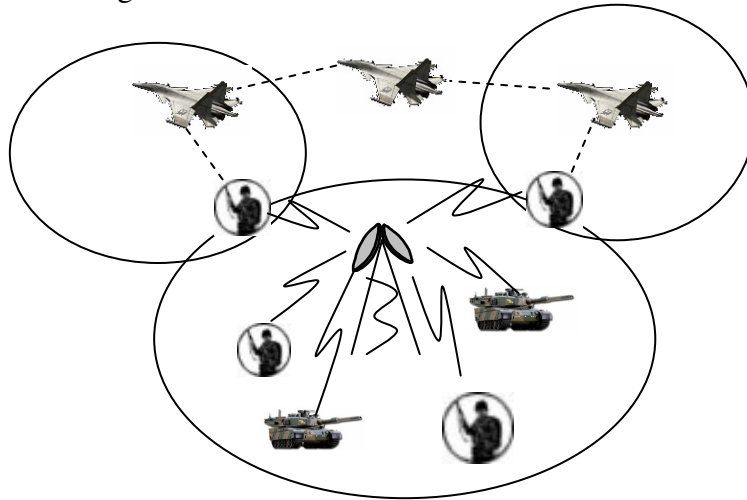


Figure 2 Mixed Network Model

The reason for the creation of this hybrid network can be found in the iNET Needs Discernment Study [9]. In that study, the proposed network has to satisfy certain requirements for acceptance. These requirements include the ability to provide some level of QoS, the capability to offer services over the horizon at reliably high data rates, and to facilitate bidirectional connections that are capable of supporting real-time and non-real-time data. The issue of Contention vs. QoS was prompted by the previous work done by Babalola [10]. In his work he developed a two stage clustering algorithm that could be used to reconfigure the network as shown in figure 3. The proposed hybrid 802.11 architecture will provide a stable access point connected to the wired network as well as an adhoc extension that will allow over the horizon connectivity.

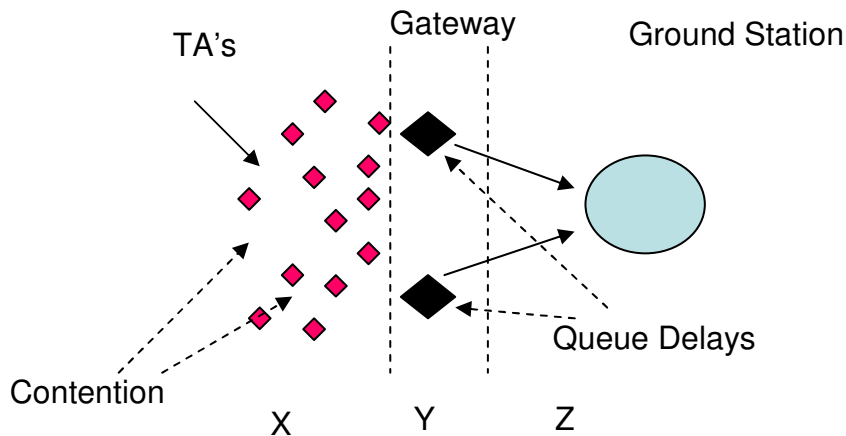


Figure 3 Information theory representation of Mixed Network

Current work is aimed at providing a framework for characterizing the performance bounds of a network with both QoS and Contention. The goal of this paper is to optimize the number of users that can share the same resource while providing a measure of QoS. By optimizing the contention mechanism of a network one is able to achieve better efficiency as well as higher confidence level for the QoS policies. This begins with an information theory analysis to show the relationship between Contention and QoS in terms of an information theory flow diagram.

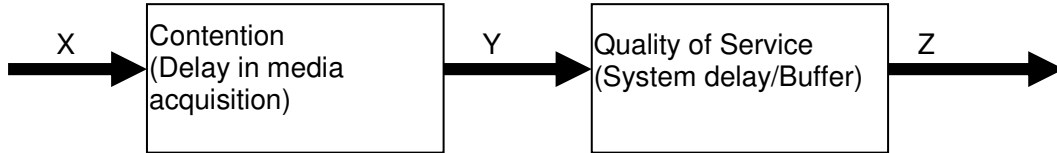


Figure 4 Flow Chart of the Mixed Network

One assumes based on the previous figure, that contention and QoS are interdependent. Therefore, the relationship of the two measures is somehow dependant on some complex relationship between the two variables. To make this analysis possible, certain assumptions have to be made about the relationship of X, Y, Z as illustrated in figure 5. The random variable X represents random binary data [1, 0]. The contention channel is modeled as a binary symmetric channel (BSC) with random variable Y as the output. The binary random variable Y is the output of the contention channel and the input to the Queue. This can also be represented as a binary symmetric channel with the binary random variable Z representing the output.

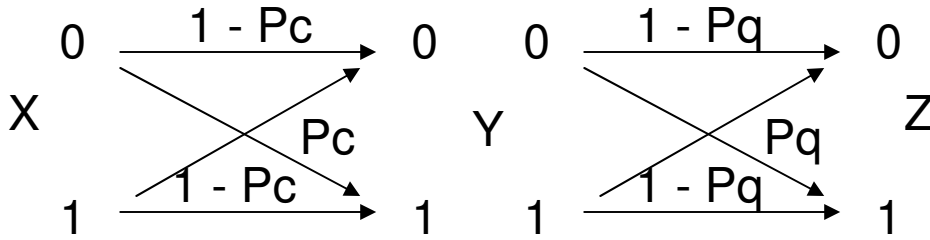


Figure 5 Binary Symmetric Channel (BSC) Tandem Channel Diagram

As shown below the relationship between X and Z can be developed as:

$$P(X, Z) = P(Z / X)P(X) \tag{1.1}$$

If however these networks are independent

$$P(Z / X) = P(Z / Y)P(Y / X) \tag{1.2}$$

Combining these yields

$$P(X, Z) = P(Z / Y)P(Y / X)P(X) \tag{1.3}$$

,where the $P(x)$ is the probability of the binary variable X , $P(y/x)$ accounts for the probability of collision of the binary signal based on the traffic load, and $P(z/y)$ accounts for the probability of a buffer overrun.

Using the binary symmetric channel allows the development of the channel capacity. If we use the Shannon channel capacity theorem to find the maximum capacity as $C = \text{Max}(I(x, z))$, where $I(x, z)$ represent the Mutual Information between X and Z defined as:

$$I(x, y) = \sum_{x,y} p(x, y) \log \left(\frac{P(x, y)}{P(x)P(y)} \right) \quad (1.4)$$

$$I(y, z) = \sum_{y,z} p(y, z) \log \left(\frac{P(y, z)}{P(y)P(z)} \right) \quad (1.5)$$

,where $I(x,y)$ is the mutual information of the binary channel with respect to the contention for the channel, and $I(y,z)$ is the mutual information of contention with respect to the probability of buffer overrun.

To optimize the capacity of the binary channel you maximize the information values of the above equations and take the minimum value of the two. The capacity of the channel is controlled by the minimum value of the maximum values of the two stated by Shannon's channel capacity equation. These equations would provide a comparative testbed that could be used to test the effectiveness of different combinations of both contention techniques and QoS requirements for different types of traffic. The analysis of the different combinations could also lead to the formula for the interdependence of contention and QoS, which will be the basis for constructing an optimum network. This network would optimize the amount of users with the required Quality of Service levels which would lead to better efficiency and higher data rates.

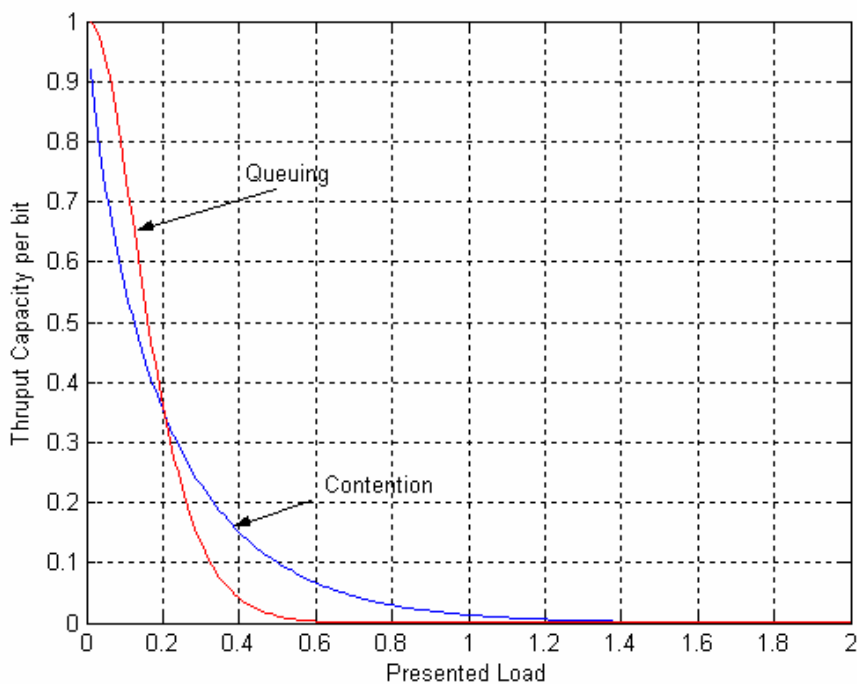
RESULTS

A simple program was written to calculate the capacity of both contention and queuing. The contention is modeled as a slotted ALOHA channel where the throughput of the channel is easily represented as a function of the presented load on the network. Similarly the priority queuing can be modeled with a finite buffer length with Poisson traffic with 10 users per queue. The capacity of the binary symmetric channel can expressed simply as:

$$C = 1 - H(p)$$

,where $H(p)$ represents the entropy of the probability of error.

For good channel conditions for the contention channel, the probability of error is .5 times the probability of a collision. Similarly for good channel conditions for the queuing case, the probability of error is .5 times the probability that a packet is dropped. Figure 5 shows the capacity of the contention channel and the queuing channel as a function of presented load for the conditions cited. These results demonstrate the strong dependence of throughput on the presented load of on the network for priority QoS traffic. The results in real networks will vary considerably. This approach however shows promise as a tool for evaluating performance of mixed networks.



CONCLUSION

A mixed network solution for iNET as proposed will present significant issues for quality of service applications. The preliminary work here shows that models for contention and queuing will enable performance analysis to support this development. The throughput expression for contention and queuing shown here can now be used to evaluate various schemes. It remains to develop models for the delay associated with such schemes. Future work will develop models such that various design approaches for contention and queuing can be evaluated and selected. In addition such measures may be used to organize the nodes in a mixed network

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