Load Weight Based Channel Access Protocol

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Abstract. The Stochastic Unified Multiple Access (SHUMA) channel access protocol provides effective access to Link-16 time slots for fluctuating numbers of users without slot reallocation while minimizing collisions. The performance of SHUMA protocol will be degraded under load unbalance. Our goal is to design a Link-16 multiple access protocol that is simple so that it can be implemented even in the older terminals; robust so that it can operate well despite load unbalance, dynamic topology. The send probability is adaptive adjusted based on the normalized load weight of unit, then the load weight based channel access protocol is proposed. The simulation results show that the delay and throughput performance of the proposed LWCC protocol are better than SHUMA.

Introduction

Link-16 can provide air track and other command and control information to fighter aircraft, other weapons platforms [1]. Link-16 uses time-division multiple access (TDMA) protocol to assign transmission capacities to platforms. Now Link-16 is the primary Department of Defense tactical data link.

Although Link-16 is a very capable system, it has some limitations when the network is dynamic. The network is preplanning which may take several weeks. When the network is dynamic, some unplanned platforms cannot join the Link 16 network. Also, the capacities dedicated to absent platforms cannot be reclaimed. The Link-16 network protocol is designed for small networks. When the number of platforms is large increasing, the current Link-16 architecture cannot support the increasing services.

To address these important problems, the Office of Naval Research (ONR) develops the Stochastic Unified MultipleAccess (SHUMA) protocol [2].SHUMA allows Link-16 platforms to fluidly enter and exit the theater. Some dynamic slot allocation algorithms based on priority is researched in [3-4].To enhance the robustness of the data link network, some dynamic slot allocation research work has been discussed in[5-9].These researches work consider the dynamic of data link network, but the fairness is less considered when the load is unbalance.

In this paper, we consider the problem of load unbalance. Based on the different load weight of different platforms, we present a novel load-weight-based channel access protocol (LWCC). The send probability is adaptive adjusted based on the normalized load weight of unit and historical traffic. The simulation results show that the fairness of the proposed LWCC protocol is better than SHUMA protocol.

The paper is organized as follows. In Section II, the SHUMA protocol is briefly introduced. In Section III, the LWCC protocol is given. The simulation results are shown in Section IV. Finally, the conclusion is given in Section V.
System model and the Local sensing Algorithm

SHUMA allows $N_i$ users to statistically share time slot $i$, where $N_i \geq 1$. The decision of whether to transmit during time slot is modulated by probability

$$p_i(t) = \frac{1}{N_i} + \left(1 - \frac{1}{N_i}\right) \left(1 - \left(1 - \frac{1}{N_i}\right)^{B_i(t)}\right) = 1 - \left(1 - \frac{1}{N_i}\right)^{B_i(t)+1}$$

(1)

There are two parameters which determine this probability and to decide whether to access the time slot. The value of $N_i$ is determined dynamically from received PPLIs. The value of $B_i(t)$ is calculated by monitoring the unit historical traffic, the value $B_i(t)$ is added 1 with the probability $\frac{1}{N_i}$ when there is no transmitting data, and the maximization value of $B_i(t)$ is $K$. When the data is transmitting with the probability $p_i(t)$, the value $B_i(t)$ is reduced 1 with the probability $\left(1 - \frac{1}{N_i}\right) \left(1 - \left(1 - \frac{1}{N_i}\right)^{B_i(t)}\right)$.

The two parameters can be described as the outside and inside parameters, which demonstrates the number of units and the unit historical traffic.

The throughput of ALOHA protocol is given

$$S = G \left(1 - \frac{G}{N}\right)^{N-1}$$

(2)

Where $G$ is the network load. When $G = 1$, the maximum throughput can be achieved. Assume the send probability of the unit is $p$, then the success send probability $P_{success}$ is given

$$P_{success} = Np \left(1 - p\right)^{N-1}$$

(3)

When $p = \frac{1}{N}$, the maximum success send probability can be achieved. The throughput performance of SHUMA is the same with the situation when $p = \frac{1}{N}$.

LWCC Protocol

In tactical data link network, the different units have different traffic. For example, aircraft carrier have more data to transmit and other weapons platforms have the less traffic. But the fairness is important to every unit.

We define $l_i$ is the normalized load weight of unit $i$, $L_i$ is large when the traffic of unit $i$ is large. The normalized load weight of unit $i$ is given

$$L_i = \frac{1}{N} \sum_{i=1}^{N} l_i$$

(4)

Then the load of unit $i$ can be given

$$G_i = G \times L_i$$

(5)

Where $G$ is the network load.

The throughput and delay performance of SHUMA protocol with different load weight units is given in fig.1 and fig.2.
The simulation results show that the delay and throughput performance is different between different units. The SHUMA protocol cannot satisfy the fairness requirement.

In order to enhance the fairness of data link network, we propose the load weight based channel access protocol (LWCC). In LWCC, the normalized load weight is used to replace the probability \( \frac{1}{N_j} \). Then the decision of whether to transmit during time slot \( i \) is modulated by probability

\[
p_i(t) = 1 - (1 - L_i)^{B_i(t)+1}
\]

The scheme of the proposed LWCC protocol is specified in fig.3.

At reference time 0, set \( B_i(0) = 0 \).

\[
\text{if (} X_{i,j} = 0 \text{) /*no message to transmit*/ begin}
\]

With probability \( L_i \), increment \( B_i(t) \) by 1 if \( B_i(t) \) is less than \( K \).

\text{end}

\[
\text{else begin /*message to transmit*/}
\]

Generate a random number \( R \) uniformly distributed between 0 and 1.
if (R<1/L_i) 
    begin 
    Transmit a message. 
    end 
else 
    begin 
    Generate R uniformly distributed between 0 and 1. 
    if (R < (1-(1-1/L_i))^{B_i(t)}) 
    Transmit a message and decrement B_i(t) by 1. 
    end 
end

Fig.3 Scheme of LWCC protocol

Simulation Results

In this section we present some simulation results to demonstrate the throughput and delay performance of the LWCC algorithm. The results of the ALOHA and SHUMA protocols are also shown for a comparison. The parameters used in our simulations of the data link network are shown in the following table.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum distance between different units</td>
<td>300km</td>
</tr>
<tr>
<td>Slot length</td>
<td>7.8125ms</td>
</tr>
<tr>
<td>Number of slot</td>
<td>100000</td>
</tr>
<tr>
<td>Number of units</td>
<td>10</td>
</tr>
<tr>
<td>Load weight of different units</td>
<td>[10,10,2,2,1,1,1,1,1,1]</td>
</tr>
</tbody>
</table>

The units are randomly distributed within the coverage radius of 200*200 square kilometer. Then all of the units can communicate to each other in the network. Fig.4 shows the throughput performance of three different protocols.

Fig.4 Throughput performance of different protocols

It can be observed from fig.4 that the throughput performance of ALOHA protocol is poor when the network load is large, the performance of SHUMA is worse than ALOHA when the network load
is small, and the proposed LWCC protocol is the best between these protocols. Fig. 5 shows the average delay performance of three different protocols.

![Fig. 5 Average delay performance of different protocols](image)

It can be observed from Fig. 5 that the average delay performance of SHUMA protocol is poor when the network load is small, the performance of LWCC is better than SHUMA when the network load is small, and the ALOHA protocol is the best between these protocols. Fig. 6 shows the throughput performance of different load weight units when the proposed LWCC protocol is used.

![Fig. 6 Throughput performance of LWCC](image)

It shows that throughput performance of different load weight units is also the same, which is better than SHUMA which is shown in Fig. 1. Fig. 7 shows the delay performance of different load weight units when the proposed LWCC protocol is used.
It shows that delay performance of different load weight units is also the same, which is better than SHUMA which is shown in Fig.2.

Summary

The SHUMA protocol provides effective access to Link-16 time slots for fluctuating numbers of units. However, the performance of SHUMA protocol will be degraded under load unbalance. To enhance the fairness of the dynamic data link network, a novel load weight based channel access protocol (LWCC) was given. We considered the potential of using the normalized load weight of different units for channel accessing. The simulation results show that the novel LWCC protocol can provide better throughput and delay performance, then the fairness of the data link network can be improved.

References