Develop new MAC protocol for UWB with its simulation based on NS2

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Abstract

With the development of UWB, there are many MAC protocol for the UWB Networks, and they have different characters in different sides. First, some kinds of MAC protocol will be introduced, and through the analysis of them, we can't find their advantages and disadvantages. At the same time, we will explore the problems in the design of MAC protocol,. Certainly through the design of the physical layer, it is possible to make the UWB communication better, but it's won't be talked about for the reason that we just pay attention on the design of MAC protocol. After that, we will explore the key points in the design of the MAC protocol, such as now power control, privated MAC etc, which is important information for our design. In the end, the simulation based NS2 will taken to test our new MAC protocol, and we will modified the MAC protocol based on the results of the simulation on NS2. To test the MAC protocol repeatly, we can get the final design of MAC protocol.

1. Introduction

Ultra-wideband (aka UWB, ultra-wide band, ultraband, etc.) is a radio technology that can be used at very low energy levels for short-range high-bandwidth communications by using a large portion of the radio spectrum. UWB has traditional applications in non-cooperative radar imaging. Most recent applications target sensor data collection, precision locating and tracking applications.[1]

The MAC protocol for the UWB is not decided by the M-BOA league, while the DS-CDMA UWB chooses the IEEE 802.15.3 as its protocol of MAC layer. More and more researchers focus on the problem and try to make a standard for the UWB. In this paper, I also try to develop a new MAC protocol for the UWB, and the simulation of the new protocol will be taken on the NS2.

[1] http://en.wikipedia.org/wiki/Ultra-wideband

1.1 Some typical MAC protocols

In this part, some kinds of typical MAC protocols will be introduced.

1.1.1 DCC-MAC

DCC-MAX protocol use PPM-TH-UWB as its physical layer, and it's based on the Private MAC protocol and dynamic channel coding. Dynamic channel coding change the alternative interference management from through the channel code to through the controlling the transmission power. The private MAC is used to solve the problem that different signals compete for the same destination, and the solution doesn't need a common channel which is different for the older one.

1.1.2 Multi-band IR-UWB MAC

Multi-band IR-UWB MAC divide the available UWB band-width into multiple simultaneously usable bands. A multi-band approach can utilize the available spectrum well, and each transmitter sends longer pulses in one of the narrower bands. To make it more efficient, data transmissions are allowed to be contiguous.

1.1.3 Others

There are some other UWB MAC protocols, such as Sustained Link Networks(SLN), Burst-frame-based MAC, U-MAC etc.

1.2 The key points when designing the MAC protocol for the UWB

Before talking about what's is important for the MAC protocol, let's make some criterion. In the [1] , the author referred that a criterion often used is max-min fairness. But, in the situation of the mobile ad-hoc networks, it turns out that always results in all sources being allocated strictly the same rate. The criterion is inefficient, for that all links tend to be equalized to very small achievable rates. Another criterion is to maximize total capacity, or transport capacity. It is more efficient but unfairness. A compromise is to maximize a concave utility function to make the proportionally fair.

As is known by us, the MAC layer has to provide three functions: interference management, access to a destination, sleeping management. According to the three function, let's list some key points of the design of the MAC protocols, and these key points are supported by the previous researches by other researchers.

1.2.1 Whether to use power control

In [1] it is referred: it is shown in [7] that the optimal solution is achievable by a 0/Pmax strategy, and in the case of only peak power constraints (no average power constraint) any other strategy cannot by optimal.

1.2.2 Whether to allow interference

No exclusion Region for low Power: allow low power transmissions to interfere, it causes a rate reduction, but it is less compared by the loss of the mutual exclusion.

1.2.3 Whether rate control is needed

In [2] it is referred: If the transmission rate is fixed, it has to be low enough to be feasible for the worst channel conditions,. This in turn imposes the same low rate in good channel conditions. If transmission rates are low, packet transmissions last longer, and more energy is consumed to keep circuits running. This is highly inefficient from a life time or rate viewpoint. As such rate control is necessary.

1.2.4 Whether to use the multi-user detection

In [2] it is referred: A suboptimal and simple form of multi-user detection is beneficial: At the cost of a small rate reduction, it was demonstrated in [3] and [9] that interference mitigation greatly alleviates the effect of one or several near-far interferers. Furthermore, it does not increase the energy consumption since only the power of the signal of interest needs to be measured.

1.2.5 Whether to use the slotted sleeping

It is depends on the different situations. In [2] is is referred that slotted sleeping is better than unslotted if occasional bursts must be supported, and unslotted sleeping is better than slotted if occasional maximum latency must be supported.

2. Design the new MAC protocol to realize the function

There already are mac protocols which could be used for the uwb communication, such as DCC-MAC, IEEE802.15.3, IEEE802.15.4 etc. IEEE 802.15.4a task group is dedicated to the development of a low grade industrial market wireless personal area network (PAN) standard, currently group Nanotron Technologies GmbH has been selected to design the broadband chirp spread spectrum (Chirp Spread Spectrum) physical layer physical layer technology as a benchmark standard. IEEE 802.15.4a task group is dedicated to the development of a low grade industrial market wireless personal area network (PAN) standard, currently group Nanotron Technologies GmbH has been selected to design the broadband chirp spread spectrum (Chirp Spread Spectrum) physical layer physical layer technology as a benchmark standard. With last year's 802.3 UWB (ultrawideband, UWB) PAN standard was sentenced to death, 802.15.4a PAN is considered the core of the potential of UWB applications. After the first round of voting, with 94% of the standard rate of adoption through the first round of voting proponents. Then an example of the superframe structure of IEEE802.15.4 is given as follows.

For the reason that the IEEE802.15.4 solve a lot problem for the mac design of the uwb, so I will try to explore a new MAC protocol based on the IEEE802.15.4. Referred on the several effects of the uwb mac, my work is to change the IEEE802.15.4 to a new mac proctol which can suit the uwb better. The CSMA-CA technique, DBTMA technique, the entry control, power control, Qos problem will be discussed and the NS2 simulation will be given on the fourth part.

First, IEEE 802.15.4 has its various features, including: (1) beacon enabled mode and non-beacon enabled mode; (2) association, tree formation and network auto-configuration; (3) orphaning and coordinator relocation; (4) carrier sense multiple access with collision avoidance (CSMA-CA), both unslotted and slotted; and (5) direct, indirect and guaranteed time slot (GTS) data transmissions. In non-beacon enabled mode and under moderate data rate, the new IEEE 802.15.4 standard, compared with IEEE 802.11, is more efficient in terms of overhead and resource consumption. It also enjoys a low hop delay (normalized by channel capacity) on average. In beacon enabled mode, an LR-WPAN can be flexibly configured to meet different needs, such as link failure self-recovery and low duty cycle. In both beacon enabled mode and non-beacon enabled mode, association and tree formation proceed smoothly and the network can shape up efficiently by itself. [14]

Wireless links under 802.15.4 can operate in three license free industrial scientific medical (ISM) frequency bands. These accommodate over air data rates of 250 kb/sec (or expressed in symbols, 62.5 ksym/sec) in the 2.4 GHz band, 40 kb/sec (40 ksym/sec) in the 915 MHz band, and 20 kb/sec (20 ksym/sec) in the 868MHz. Total 27 channels are allocated in 802.15.4, with 16 channels in the 2.4 GHz band, 10 channels in the 915MHz band, and 1 channel in the 868 MHz band. [14]

The tasks of the MAC sublayer:

Generating network beacons if the device is a coordinator

Synchronizing to the beacons

Supporting personal area network (PAN) association and disassociation

Employing the carrier sense multiple access with collision avoidance (CSMA-CA) mechanism for channel access.

Handling and maintaining the guaranteed time slot (GTS) mechanism

Providing a reliable link between two peer MAC entities [14]

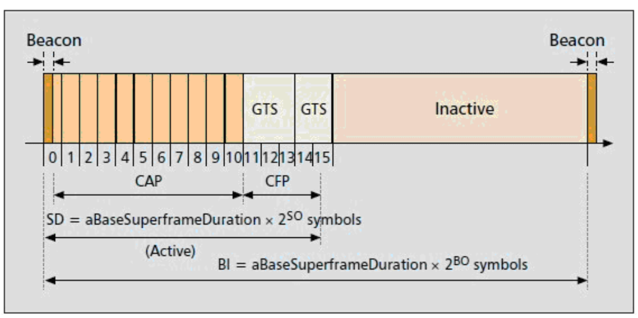

Figure 1. An example of the super frame structure[15]

The format of the superframe is defined by the coordinator. From Fig. 1, we can see the superframe comprises an active part and an optional inactive part, and is bounded by network beacons. The length of the superframe (a.k.a. beacon interval, BI) and the length of its active part (a.k.a. superframe duration, SD) are defined as follows:

BI = aBaseSuperframeDuration x2^{BO}

SD = aBaseSuperframeDuration x2SO

Where,

aBaseSuperframeDuration = 960 symbols

BO = beacon order

SO = superframe order

The values of BO and SO are determined by the coordinator. The active part of the superframe is divided into aNumSuperframeSlots (default value 16) equally sized slots and the beacon frame is transmitted in the first slot of each superframe. The active part can be further broken down into two periods, a contention access period (CAP) and an optional contention free period (CFP).[14]

3. Simulation on the NS2 and some modification of the new MAC protocol

Fig 2 shows the 802.15.4 MAC in the NS2 simulator, it is the main module. It implements all the 35 MAC sublayer primitives.

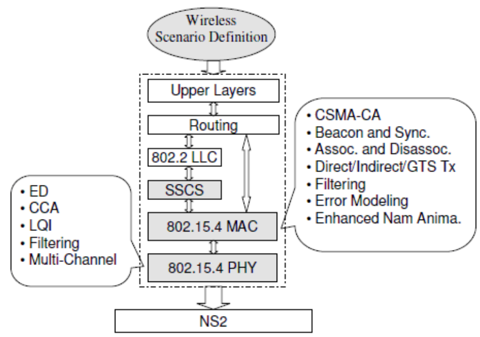

Figure 2. NS2 Simulator for IEEE 802.15.4 [14]

The association procedure is a multi-step procedure as briefly described by the following pseudo code (for device part only):

1: channel scan
2: if coordinators not found
3: association fail
4: elseif no coordinators permit association
5: association fail
6: else
7: select a proper coordinator
8: send association request to the coordinato.
9: wait for ACK
10: if ACK not received
11: association fail
12: else
13: send data request to the coord.
14: wait for ACK
15: if ACK not received
16: association fail
17: else
18: wait for association response
19: if asso. response not received
20: association fail
21: elseif association not granted
22: association fail

23: else
24: association succeed[14]

Then I simulate a demo to show the process. In this demo, the node 0 performing active channel scan first, then node 0 begin to transmit beacons. So node 0 successfully started a new PAN(beacon enabled). Next, at 0.5 second, node 1 performing active channel scan then find the channel. So node 1 sending association request to channel11 to node 0, the coordinator. Node 0 send back a n ack for association request command to node 1. Then node 1 send data request command to node0, node0 send an ack for data for data request command and association response command to node1, so the association between node0 and node 1 is successful. Node1 begin to synchronize with the coordinator node0. At 1.5 seconds, node2 repeat the process the same with node 1. Then node3, ndoe4, node5, node6, node7, they synchronize with node0 in order.

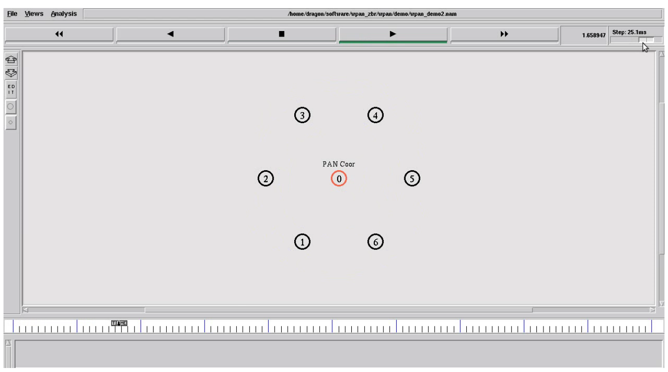

Figure 3. orignal demo in a right order-1

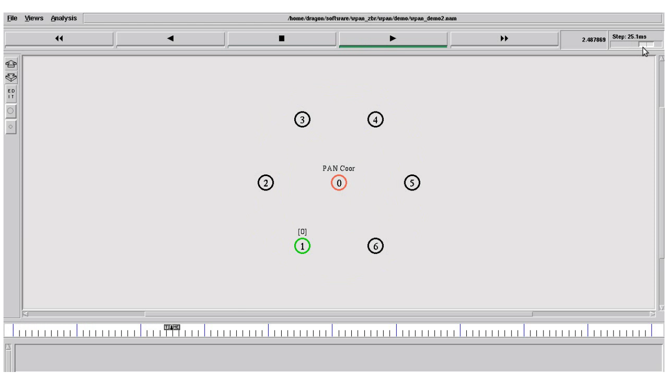

Figure 4. orignal demo in a right order-2

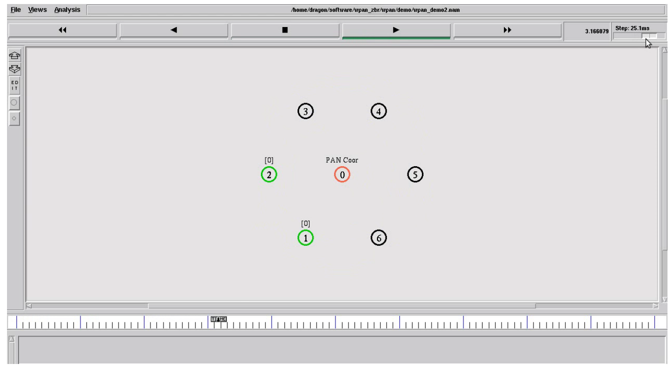

Figure 5. orignal demo in a right order-3

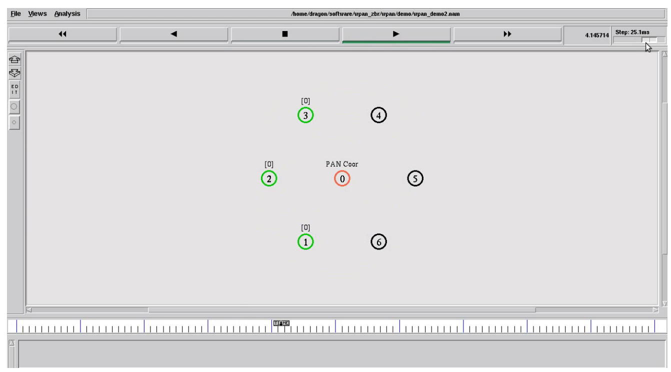

Figure 6. orignal demo in a right order-4

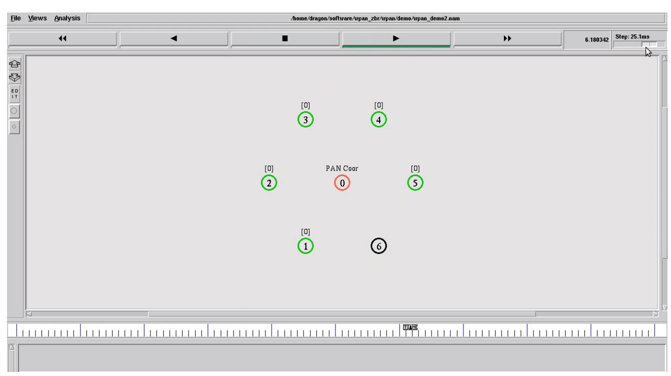

Figure 7. orignal demo in a right order-5

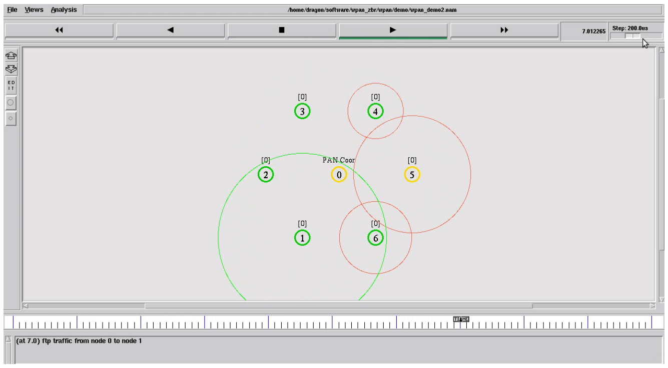

Figure 8. orignal demo in a right order-6

In the case referred before, the process is successful, but in the fact, if the time during which the applications happen is changed, then the result was totally different. When the time is changed, the demo is as following:

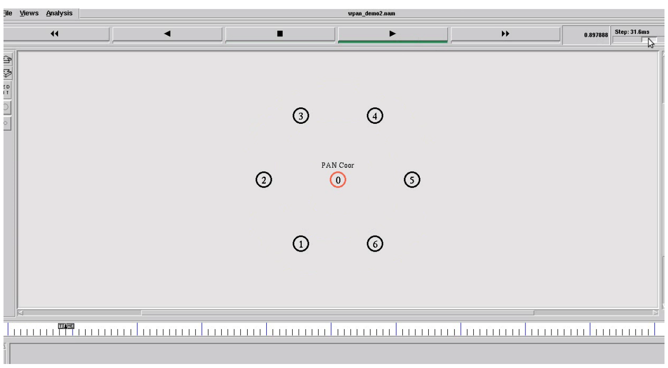

Figure 9. orignal demo in a wrong order-1

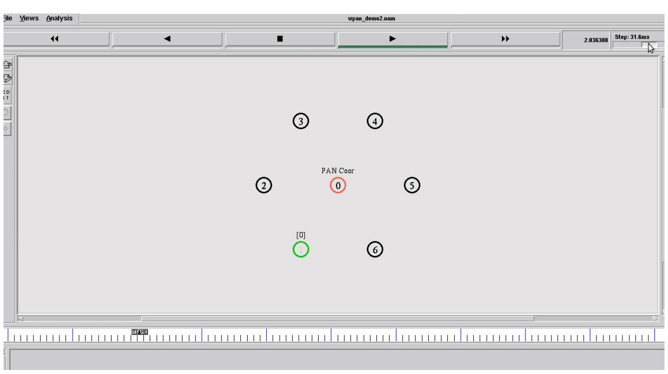

Figure 10. orignal demo in a wrong order-2

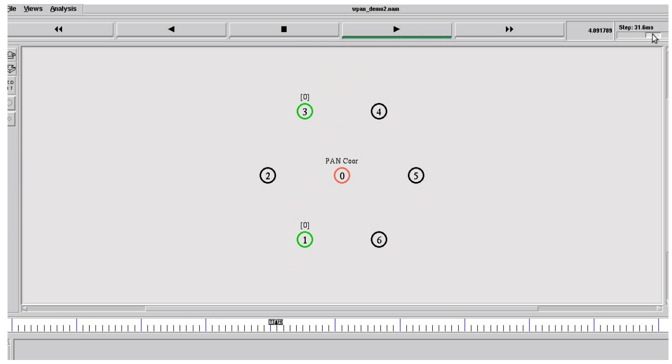

Figure 11. orignal demo in a wrong order-3

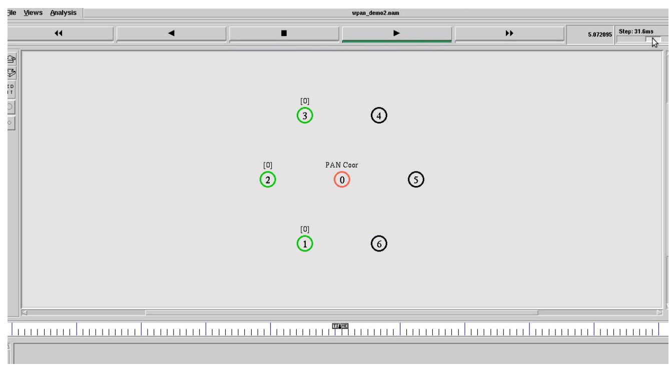

Figure 12. orignal demo in a wrong order-4

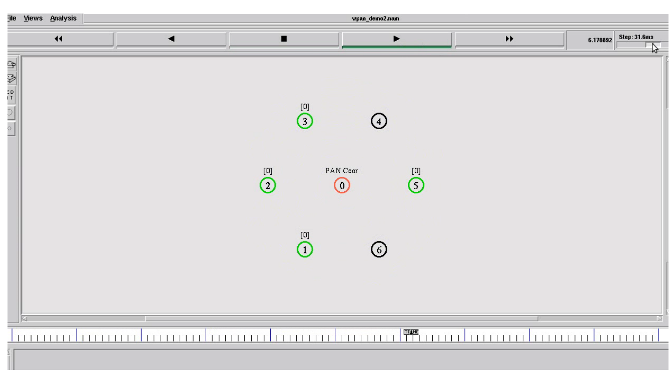

Figure 13. orignal demo in a wrong order-5

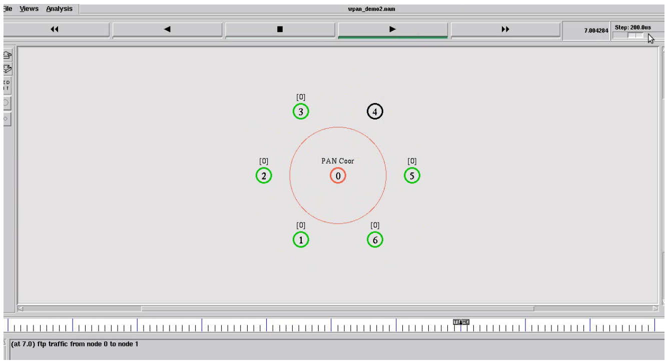

Figure 14. orignal demo in a wrong order-6

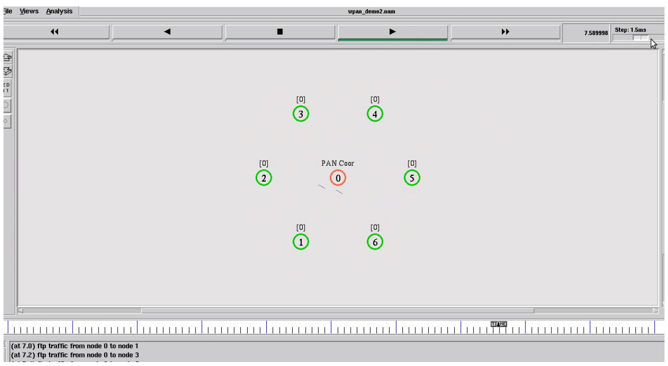

Figure 15. orignal demo in a wrong order-7

In this demo, the node 0 performing active channel scan first, then node 0 begin to transmit beacons. So node 0 successfully started a new PAN(beacon enabled). Next, at 0.5 second, node 1 performing active channel scan then find the channel. So node 1 sending association request to channel11 to node 0, the coordinator. Node 0 send back a n ack for association request command to node 1. Then node 1 send data request command to node0, node0 send an ack for data for data request command and association response command to node1, so the association between node0 and node 1 is successful. Node1 begin to synchronize with the coordinator node0. But at 1.39 second, node 2 sending the association request command to node0 and received the ack, but at 1.78 second, node1 sending data request command to node0 and interrupt the communication between node2 and node0, which lead to the result that the node 2 can't synchronize with node0. Then node2 will apply later, but reject again and again because of the time problem.

So, in this case, we can find that the order to synchronize with the node0 will be disordered if the time to apply is different. In the daily life, we will feel the response time of a TV or light is too long in some situation, which is bad to the protocol.

My modification is trying to solve the problem of disorder through adding the head to the mac. The addition part can record all applications and arrange them in a certain order to avoid the competition. Set a variable lasttime to record the time that when the previous is finished. Then send the waittime to the node which apply for the coordinator. Then calculate the lasttime again to get the new lasttime. More detail can be found in the [16].

And the result is as follows:

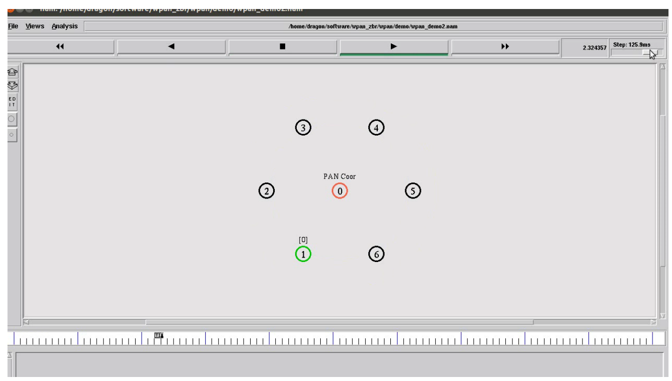

Figure 16. modifid demo in any order-1

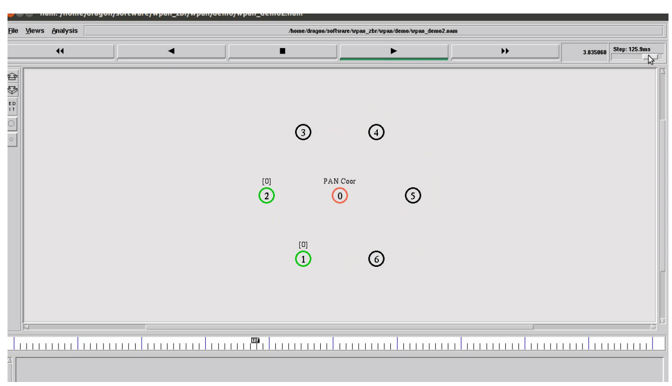

Figure 17. modifid demo in any order-2

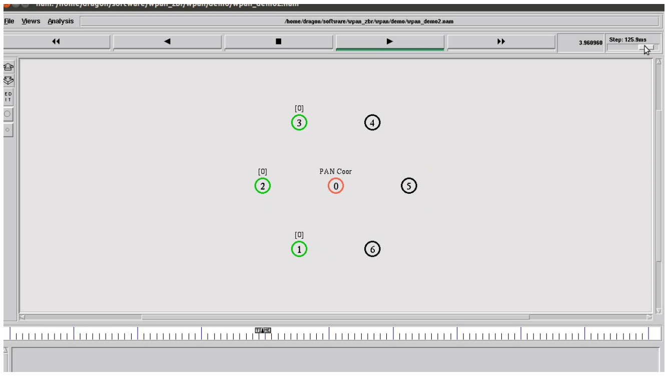

Figure 18. modifid demo in any order-3

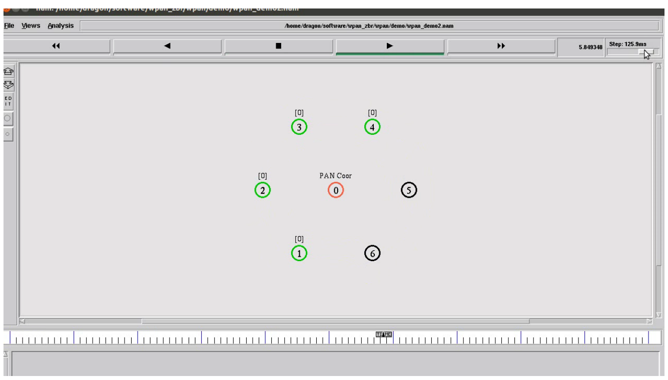

Figure 19. modifid demo in any order-4

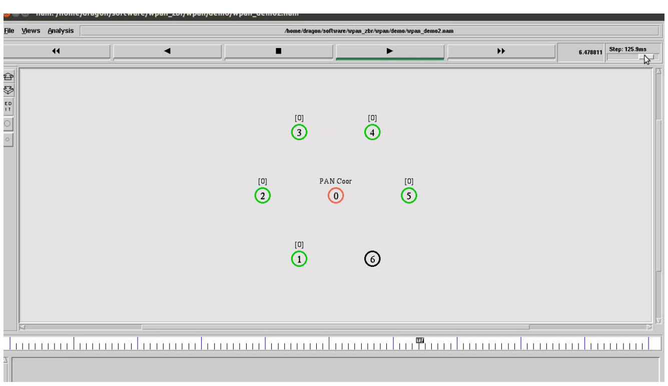

Figure 20. modifid demo in any order-5

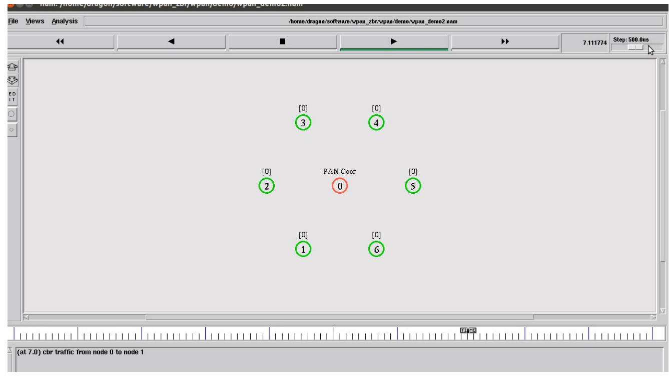

Figure 21. modifid demo in any order-6

4. Conclusion

From the result, we can find that the modification can work very well in the model referred before and the order is right no matter when the applications are put forward.

On the other hand, we realize that there must be a clock on the coordinator. So the model is just suitable for star topology, instead of tree topology. Because in tree topology, there are many clocks should be set up, which cost much in fact.

In a word, such a modification may contribute to some certain situations.

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