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Analysis and Simulation of Networking Protocols in Constellation Flying System for Inter-Satellite Communication

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Abstract— The High rate of transmission of data makes IEEE 802.11 protocol ideal for WLAN (Wireless Local Area Network). The configuration of the flying satellite is such that the distance between the satellites is very short and much alike WLAN, hence to elevate the throughput IEEE 802.11 protocol can be used for the inter-satellite communication. Nevertheless the fact is that the inter-satellite distance is large as compared to the distance in WLAN. Thus IEEE 802.11 protocol needs to be altered and optimized to make it usable for configuration of inter-satellite communication. Two variants of MAC namely Distributed Coordination Function (DCF) and Point Coordination Function (PCF) are examined for the configuration of flying satellite system. Inter-frame reformulation, merging of smart antennas with the protocols proposed in MAC and the acceptance of the minimal contention window are suggested in this paper. In the end we examine the performance of the altered protocol after simulations.

Index Terms— IEEE 802.11, Distributed Coordination Function, Point Coordinition Funcation, Modified 802.11 Protocol, Configuration flying system, Inter-satellite communication

1 INTRODUCTION

Humanity underwent severe losses due to the natural calamities such as Hurricane, Tsunami, and earthquake. Since few years the group of small satellites for keeping track of the Earth's surface using the LEO (Low Earth Orbit) has been identified as serviceable platform for robust monitoring of the natural calamities. The constellations of the small satellites are used in 3D surveillances, radar imaging, and indirect traffic analysis and so on [1]. To perform the tedious space missions the constellation of satellites have to swap and pubis data among each other and build assured communication link between satellites. In case of radar satellites using microwave in distributed manner with high focus having synthetic cleft optical surveillance satellites, the distance among the satellites ranges from 550 meters to several kilometers and communication between them is much like WLAN without complications in controlling the network layer functions like routing and access control. It depends on the functionality of physical layer and MAC layer of OSI model. The concept of IEEE 802.11 protocols is used to roll up the rate of transmission of data.

In satellite network, the satellites are connected with each other by ISL (Inter satellite Link) and the rate of transmission of data change rapidly because of the mobile nature of the satellite and frequent change in the network topology. In Low Earth orbit satellites the signals have very less SNR (signal noise rate), variations in difference of transmission and huge Doppler shift. It is essential to analyze variations in the parameters of the orbit which might affect the protocols involved in ISL and also to verify whether the wireless protocols used in terrestrial scenarios can be implemented in case of ISLs.

The important aspect of our current work is the modification of existing 802.11 protocol. With the improvement in the configuration of the flying technology the throughput of small satellites expected to increase rapidly. IEEE 802.11 is functional in four stencils namely DSSS (Direct Sequence Spread Spectrum), FHSS(Frequency Hopping Spread Spectrum), technology using infrared transmission operating in 2.5 GHz band and OFDM(Orthogonal Frequency Division Multiplexing) operational in 5.85 GHz band. To fulfill the demands of communication in space few modifications of parameters in MAC layer is done for 802.11 protocols. The format of the paper is as depicted below: Configuration of flying scenario, examination and modification of MAC layer protocol to fulfill the requirements for configuration of satellite system. At the end the simulated results and the performance are evaluated.

The flying constellation of satellites comprises of many small satellites that together form a network such that the functionalities of a single space vehicle are not compromised. As compared to the conventional satellites the constellation has the following pros: cheap, robustness and scalability. In our paper the configuration which we are using is Flower constellation in Low Earth Orbit satellites. The flower constellation can be categorized as Circular and Triangular.

2 LITRATURE SURVEY

The most crucial factors in disaster monitoring from space is the time of response, i.e. the delay between the dispatching of the service request and the delivery of the data to the customer. In past it used to take months of surveillances remotely which is a matter of no more than 48 hours in case of exception with mostly persisting two to four hours presently. The justification for this delay could be in technical or environmental limitations. For most applications the resulting delay in capture of image and delivery is not acceptable, in particular for rapid response systems addressing natural and man-made disasters, an obvious case being Tsunami where the warning needs to be issued in a matter of minutes. In such cases almost instantaneous data availability is a strict requirement to enable an assessment of the situation and instigate an adequate response.

Kawsu Sidebeh and Tanya Vladamirrova in their paper [2] is concerned with adaption of the IEEE 802.11 protocol for ISLs between the satellites in formation with the aim of quick response and surveillance of the disaster using the LEO satellites. Key features of the optimization technique used involve the modification of the variables of the physical layers and betterment of the DLL of 802.11 protocols.

Tanya Vladamirrova and Kawsu Sidebeh in their paper [3] looked in to the main characteristics of the optimization methods to inherit the COTS (Commercial of the Shelf) which is the official standard for the communication among the satellites wirelessly in independent formations.

Kawsu Sidibeh and Tanya Vladimirova in their paper [4] describes the crucial methods for optimization purpose aiming the extension of wireless network incorporated in terrestrial platform to make it usable in space for communication among the satellites. The IEEE 802.11 re-definition of the space between the frames with higher range is tested. Steering of the antennas at null values and DA (direction-of-arrival) algorithms for reducing the occurrence of interference and maximizing the throughput are addressed.

3 IEEE 802.11 PROTOCOL FOR MAC SUBLAYER

The most important purpose of the IEEE 802.11 MAC sublayer is to enable station for transmitting data wirelessly quickly and effectively and also synchronized use of the medium. The access to the medium is done by two ways namely DCF and PCF.

3.1 *Distributed Coordination Function (DCF)*

In DCF [5] the stations contest for the access to the wireless medium in a fair fashion. Thus it is a competitive platform. DCF makes use of the Collision Avoidance with Carrier Sense Multiple Access CSMA/CA with binary exponential back off algorithm. Every station keep sensing the medium to check whether the channel is busy or not. If the channel is found out to be busy then the sensing procedure continues else it waits for sometime which is called the IFS time period which is the space between the two consecutive frames sent and then the transmission procedure starts. During the wait if any other station initiates the transmission then the station immediately stop the prolong their access. In case this wait times becomes larger than the inter-frame space the further delay in transmission occurs which is chosen as per the random back off algorithm. It is when this timer become zero the station is permitted to transmit over the channel. To check the idleness of the channel there are two methods- Physical and Virtual Carrier Sensing which is evaluated by the strength of the signal received. The next step is accomplished by using the information which predicts the state of the channel in future which may be done by the RTS/CTS frame exchange as the RTS/CTS frames contains space for storing the domains of Identification and duration with the use of which the next time slot for channel to be in idle state can be predicted. Also Network Allocation Vector (NAV) declares the state of the channel as occupied or idle.

3.2 *Point Coordination Function (PCF)*

PCF [5] work in centralized way such that PCF makes use of a point coordinator which act as the access point (AP) of the BSS for the allocation procedure that takes place by polling. Thus, it is collision proof and is suitable for applications where the requirement of time delay is must such as multimedia and voice. As the CFP (Contention Free Period) begins, the PC senses the channel. A beacon frame to start the CFP is sent whenever the idle time becomes equivalent to the PIFS (Point Coordinator Function Inter-space Space).

The station has to wait for a small span of time referred to as the Interframe space after which the transmission of the data takes place if data is available else it transmit CF-POLL (Competitive free polling frame). After which station waits for the station interframe space and if data is sent, acknowledges it with response frame else the channel is evacuated by NULL frame. If the wait time is more than the station interframe space the poll is done repetitively and the number of repetitions is a parameter which can be configured. The station is skipped when the polling time is crossed without any response which again has to undergo the polling procedure at the start of the next Contention-free period which is again configurable. [6]

4 MODIFIED 802.11 PROTOCOL FOR USE IN SPACE

4.1 *IEEE 802.11 Alteration of Inter-Frame Space for Inter Satellite Link Range*

In Low Earth Orbit Scenario the propagation delay among the satellites is in terms of milliseconds but it is scaled up in terms of microseconds in case of terrestrial wireless networks which is quiet large.[9][10]

There are four main types of intervals in 802.11 which are Distributed (DIFS), Extended (EIFS), Priority (PIFS) and Short Interframe Space (SIFS). In 802.11 the interframe space for SIFS and DIFS is 10us and 50 us respectively which are valid only for the range over 300 meters. While considering a circular configuration of 8 satellites, the distance between the orbits of the satellites is around 3200 kilometers. The Radio Frequency signals prorogation speed is equivalent to that of light which is 22 milliseconds of round trip time. As illustrated in the figure the access control time need to be edited for its adaption for inter satellite link.

Various parameters of the IEEE 802.11 namely acknowledgement time, slot timings which depends on the propagation time in air which increases with the increasing distance among the satellites and hence the various parameters need to be readjusted to make it compatible for use in satellite.

In order to fulfill the range and variance criteria of the Inter Satellite Link the IEEE 802.11 protocol’s physical and MAC layer need to be optimized. As we know that 802.11 were framed for the terrestrial application this is operable in the 300 meters range with a transmission power of roughly 1 Watt [6]. The WLAN may be categorized as Ad-hoc (Independent BSS) and infrastructure BSS. The major method to access the channel is DCF (Distributed Coordination Function).

4.2 *Use of Smart Antennas with the MAC layer of IEEE 802.11*

The main issue with the unreliable 802.11 protocol with MAC function is that when the satellites are in the polar region the distance between them contracts which results in high interference. The communication among the satellites is halted when it reaches the poles to curb interference which results in reduced connectivity among them [6].

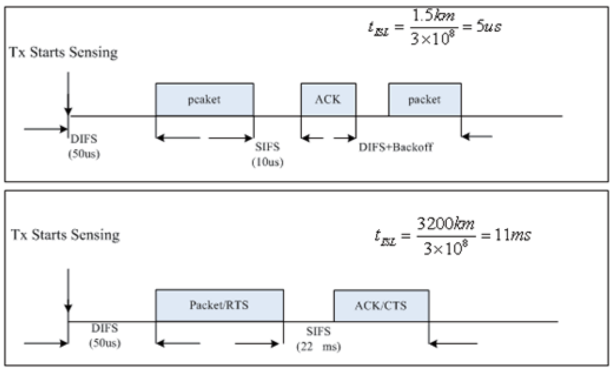

Fig. 1 IEEE 802.11 inter-frame definition scenario

In our paper we are making use of Adaptative Antennas. These Beam creators' control over the directions is of high degree but it comes at the cost of high complexity in hardware and huge investment [7]. In the receiving mode the antennas are operational in two modes namely bidirectional and Omni-directional. The bidirectional mode is for transferring the data which is done by the single beam meant for higher gain targeted towards the desired node and the Omni-directional is used for the handshaking purpose which is the swapping of the RTS/CTS packet and also during the creation of the beam [12].

4.3 Adaption *of the Contention Window Dynamically*

Different mobility aspects have been studied in context of the terrestrial applications of WLAN. This is necessary as the satellites are extremely mobile in nature and connectivity is the major issue here. BEB Algorithm is the main component of CSMA/CA, when the status of the channel changes from busy to idle, and if station is ready to send the data it get into the competitive window(CW)[8] after waiting for DIFS (Distributed interframe space) and the back-off time is randomly calculated in the trial to have access of the medium. It is the duration of CW that the avoidance of the collision takes place. After every failure in transmission back off time is randomly selected this is in the range of zero to CW-1. The duration of the competition window increases linearly with the increasing value of the timer. With the occurrence of every collision the CW is increased mulplicatively by a factor of two from 31 to 1024[11]. The results of setting a predetermined value for minimum of CW in a network which is very dynamic in nature are (a) unwanted MAC delay caused by the huge back-off time limiting the throughput, (b) partiality between the nodes which are connected, (c) increased delay of even those nodes which are not much loaded, (d) large quantity of collisions occurring in case the node is loaded heavily. In order to optimize the throughput the minimum value of the contention window has to be approximated as CWmin is based upon the count of the stations. A Contention Window Dynamically algorithm is proposed to get the desired success ratio by dynamically adapting the competition window [13].

Initialize CWmin =31;
Measure average (Nc) and average (Ns) over Ts Seconds;
Threshold= 0.2;
If (SR= Nc/Ns)> Threshold
  CWmin= CWmin/2;
Else
  *CWmin= CWmin*2;*
Transfer packet
Initialise Nc and Ns again
Set Nc=0;
Set Ns=0;

Where Nc and Ns are number of packets collided and the packets delivered successfully respectively. The CW algorithm which is adaptive in nature will permit the satellites moving close to each other to dynamically set their back-off time instead of using pre-decided initialized values.

5 SIMULATION AND ANALYSIS

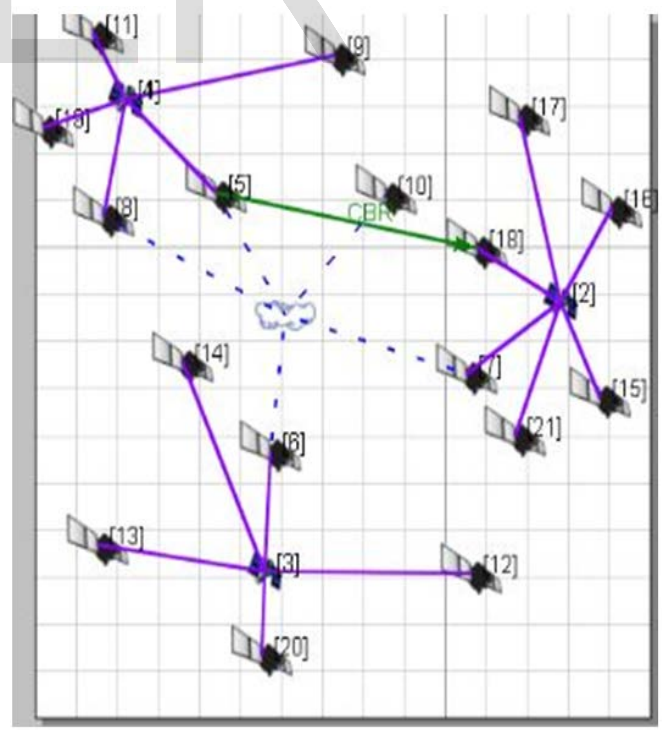

Fig. 2 Network Scenario for Three Satellite Configuration

5.1 *Satellite Nodes Configuration*

The configuration of Satellite devices compromises of infor-

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mation source and receiver, MAC protocol group of IEEE 802.11, and the interconnection between IEEE 802.11 protocol and the user layer, as display in figure 2. In the below Figure, three satellites are interconnected with each other using wireless medium and each satellite have satellite-devices in range of their base. The sending and receiving ports are mainly related to the configuration of physical layer parameter using direct sequence spread spectrum. The other Parameters are 2.4 GHz band, transmission ccrate of 1Mbps, and the transmission power is 0.1W. The main purpose of our paper is to simute the results by using c DCF

5.2 *Numerical Results and Analysis*

Consider the simulation time of 500 seconds using PCF and DCF are used separately with only the application and the routing fields active in the statistics and routing field in the scenario properties. Contention free period interval is set to 20ms and beacon frame interval to 20ms. For communication among the satellites we made use of the CBR link between satellite device5 of satellite 1 to satellite satellite device15 of satellite 2 as shown above.

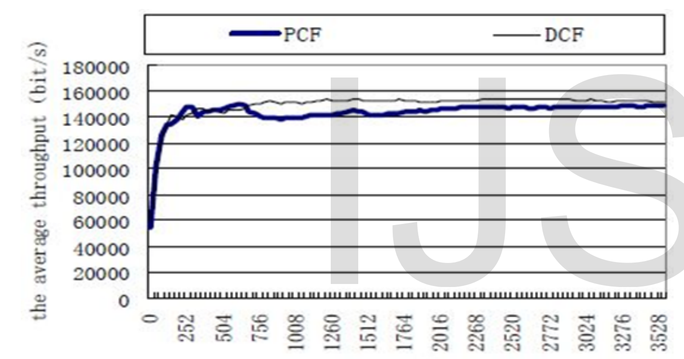

Fig.3 The Throughput Comparison Graph of three-satellite Configuration

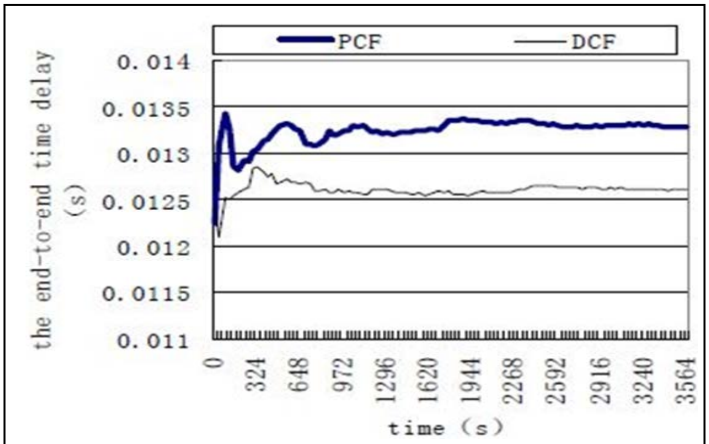

Fig.4 The Delay comparison Graph of three-satellite Configuration

Figure 3 and figure 4 shows the analysis of performance of the tuned DCF and PCF in the three-satellite configuration, which includes the average throughput and average end-to-end delay

The graphical analysis (Figure4) confirms that initially the throughput of PCF is better than DCF, but as the load increases PCF degrades. Similarly the graph plot of end-to-end delay vs time shows that the relative delay is larger in case of PCF. Hence for the three constellation configuration DCF performs better than PCF.

6 CONCLUSION

The simulation results depict that by modifying the various parameters of the physical layers of IEEE802.11 protocol such as timing of the slot, CWmin and Short Interframe Space the execution improve in space for the Inter Satellite Link. Also modification in various variables of orbit and introduction of the various shapes affect the use of the 802.11 protocol for communication among ISL. Simulation show that the results of Modified DCF and the PCF are different where the tuned DCF is suitable for the inter satellite communication where the load is less. Merging of the adaptative antennas system with 802.11 pledges that the interference will be minimized among the satellites with maximum gain and elevated throughput. The importance of this approach lies in the fact that 802.11 is extended to ISL of larger range with minimum negative effect on throughput.

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