
Kent State University, October 2006
Student – Jorry Palm
Advisor – Dr. Javed Khan

Abstract:
The rapidly and evolving nature of network technologies and service demand have led wireless technology to expand and evolve. It seems that wireless will be the core technology for building Space Networks. The cost of maintaining any wired network will be prohibitive. Space will require however, a robust, efficient, flexible and reliable wireless protocol. It seems that current 802.11 and 802.16 wireless protocols have been designed for earth network and may not conform to the constraints, QoS, and control required for a Space network. One such scenario is formation movement. In this fellowship I propose to study the impact of various formation flying scenarios over the performance of 802..1/16 wireless elements.

1 Introduction
Due to the obvious nature of creating a space network the use of a physical medium will be very limited; therefore, wireless technology will be the chief technology. Two of the most prolific wireless protocols are 802.11 and 802.16. If they are going to prove effective, problems must be uncovered now with simulation and in-depth analysis. We are going to introduce, analyze, and engineer a possible solution to a major problem concerning the utilization or the fore-mentioned wireless protocols with the most optimal satellite flying formations. These formations will provide significant relevance to how a base station will maintain a constant and reliable connection.

It seems formation flying will be used in many science projects both in near surface and on surface gang science and exploration experiments. A group of satellites, a group of flying crafts, a group of rovers loaded with complimentary science devices, will be used in complex observation and exploration experiments. A technology like 802.11/16 will be needed for group communication. It seems this space wireless must include efficient support for formation flying.

Indeed, there will be many kinds of predicted movement scenarios in space. An example is orbital movement. Almost all satellites are in continuous motion with respect to each other. It is important to study the effect of these movements on the underlying networking protocols and algorithms. One interesting starting point
seems to be formation flying which also includes orbital movement. I would like to study this in this fellowship.

2 Limitations of 802.11

2.1 Coordination

If there is no control and coordination all stations are free to speak whenever they want. This method is sloppy and very error prone. In example (a) the hidden station problem is illustrated. Since not all stations are within radio range of each other, transmissions going on one part of a cell may not be received elsewhere in the same cell. In this example, station C is transmitting to station B. If A senses the channel, it will not hear anything and falsely conclude that it may now start transmitting to B.

In additions there is the inverse problem, the exposed station problem illustrated in (b). Here B wants to send to C so it listens to the channel when it hears a transmission. It falsely concludes that it may not send to C, even though A may be transmitting to D (not shown).

2.2 The 802.11 standard control modes

2.2.1 Distributed Coordination Function

DCF does not use any kind of central control. In CSMA/CA (CSMA/with Collision Avoidance) it senses whether or not the channel is busy and if it is idle, it will then send the entire frame. It does not sense the channel while transmitting but emits its entire frame, which may well be destroyed due to interference at the receiver. Another mode of CSMA/CA using virtual channel sensing (image 2)
Through the use of acknowledgements, timers, and NAVs (Network Allocation Vectors) or virtual busy signals, the traffic is better handled. But DCF mode still has no central control and station must compete for air time, allowing for no guarantees of QoS. In the design of 802.11 standards the time intervals

### 2.2.2 Point Coordination Function

DCF is improved upon with PCF. In this mode the base station polls the other stations to see if they have anything to send. Also, because transmission order is completely controlled by the base station in PCF mode, no collisions ever occur. The basic mechanism for the base station to broadcast a beacon frame. This beacon frame contains system parameters, such as hopping sequences, dwell times, and clock synchronizations. This allows for a station that has signed up for the polling service to connect and be given a constant amount of bandwidth enabling it to give quality of service guarantees. The second reason this will be our primary choice is that it saves on power. The polling station can put its receivers to sleep during periods of inactivity.

### 2.3 Time Control

In 802.11 the access to medium by the participants of a conversation, as well as by the other waiting party is coordinated by carefully setting the intervals SIFS, PIFS, DIFS, EIFS. After SIFS only the parties of an ongoing conversation can speak (and send ACK, new fragment etc.), if no body speak in this interval, then the access point can speak until DIFS. This is to send beacon. If there is no access-point, then between DIFS and EIFS other DCF stations can send a request to send and grab the channel. Now these timing are dependent on the length and the distances.

If these are too long then there will be more silent period overhead. On the other hand they cannot be arbitrarily shortened if distances between the furthest elements are large. Thus, the size and extent of the network will have severe impact on the performance of a network. It is even more problematic if that keeps on changing. There, will be similar impact on the power requirement.
2.4 Elastic Topology

Both 802.11 and 802.16 are meant to be static protocols. It is not known exactly what will happen once you introduce the notion of a all wireless network where all are moving. Through analysis and the creation of a visualization tool, we will look at the effects of an elastic constellation formation of satellites and there effect on QoS.

As it would be clear by the above the distance and relative locations of elements have serious impact on the co-ordination protocols used in either DCF or PCF mode. In earth systems these are exceptional events and have not been a serious concern. But in space, these will have serious effect on the overall performance of the coordination schemes that are being used.

802.16 has some very interesting possibilities for becoming very mobile, thus simulating bandwidth performance on a different satellite formations is key to determining the feasibility of the protocol in space.

There are several formations in which satellites can be arranged.

- Constellation - The satellites are moderated space at considerable distance from one another but can maintain communication with one another as well as with ground stations
- Cluster - small group of satellites are located relatively close to each other as they follow orbits that permit them to remain the same distances apart.
- Trailing- One satellite which follows the first satellite in the same orbit.

3 Simulation & Research Analysis

Through simulation and Analysis we are going to understand completely, describe and document some very major problems.

- Satellites distance increases in reference to the station?
- Different formations effect on the over all QoS.
  - Which will be the most optimal for space network?
- How will dwell times be effected in a dynamic and elastic network topology
• Can 802.16 be effectively modified to be mobile along with reliable as a connection oriented protocol.

3.1 Research Rationale
In order to simulate and engineer a solution a large amount of effort will go into researching each of these topics. The knowledge gained through simulation and analysis will then provide the means to engineer an accurate and optimal solution to best formation flying configuration and the 802.11/16 protocols major pitfall of being static. The knowledge gained from this study will allow us to propose the enhancement to the protocols for formation flying environments.

Research Plan and Milestone

Jan 15 – May 15, 2007 Available part time (spring semester)
I will work half-time with NASA colleagues to get myself acquainted with NASA formation flying/predicted movement mission scenarios. I will work half-time with my advisor at KSU to learn more about how 802.11/802.16 protocols work.

May 15 – Aug 25, 2007 Available full time
After research on wireless protocols, I will focus my time and efforts fully on the simulation (if needed create tools) and in-depth analysis of the effect formation flying and the elastic nature of the topology has on 802 wireless protocols 11 and 16.

Part-time will be dedicated to working with my advisor to complete simulation and fully understanding results. Part-time will be spent with NASA colleagues to verify simulation and analysis.

Aug 28 – Dec 15, 2007 Available part time (fall semester)
I will use the information from the study to complete a presentation, and a paper. Part-time will be to work with my advisor to see if we can suggest modification to co-ordination technology to better accommodate the formation flying. Part of the time spent with NASA colleagues will be used to verify the solution with simulation and analysis.

Jan 15 – May 15, 2008 – Completion of fellowship
Complete the fellowship with documentation of study, analysis of the space network, and documentation of engineered solutions to the problem.

Budget

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Advisor will use total of about 1.2 month salary at 10K for advising the student during the 1 year period of fellowship.