COLLISION AVOIDANCE IN SENSOR NETWORKS WITH MESH TOPOLOGIES

Bakin Eugene

Saint-Petersburg State University Of Aerospace Instrumentation,
Saint-Petersburg, Russia
tel: +7-812-535-16-04
jenyb@mail.ru

Abstracts

Sensor network with topology "regular triangle mesh" is investigated in this paper. Logic structure is "many-to-one". An algorithm of calculation of optimal schedule minimizing average delay is developed.

I. Introduction

This paper is devoted to a problem of wireless control and monitoring systems development. Such systems are widely used on the plants, medical centers and security systems due to their advantages against wired ones. Absence of necessity of ducting of cables and low energy consumption make the wireless system cheap and flexible and eases process of deploying and modernization. Thus development of wireless control systems is very promising area of technical science.

One of the main problems in such systems operation is collisions presence. We name "collision" one of the following three situations (see fig. 1):

1. one transmission makes a cross talk to another one (fig. 1a);
2. sensor appears to be both receiver and transmitter (fig. 1b);
3. two sensors try to transmit their messages the third simultaneously (рис. 1c)

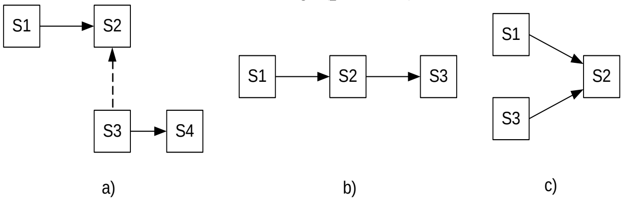

Figure 1 – Three types of collisions

For collisions avoidance method of schedule can be used.

II. Method of schedule

Lets discover sensor network containing N sensors and the base station (BS). Time is split into *slots* – time intervals which duration is equal to duration of the message plus extra guarding interval: $\tau = \tau_{msg} + \tau_{grd}$. We assume that all the messages have equal duration. Such assumption is right for the networks all the sensors of which control similar parameters of the environment [1]. Each of the transmission is appointed to one of the slots. *Duty cycle* is a slots sequence during which BS gets all the N messages (one message from every sensor) [2]. Power of set of transmission ***P***, fulfilled during duty cycle, is equal to $L = |P| = \sum_{i=1}^{N} l_i$, where l_i - the number of retransmissions, that are to be done to deliver *i*-th sensor's message to BS. Differently l_i - length of the route, connecting *i*-th sensor and BS. Each of L transmission is to be attached to ones of the slots so that there were no collisions.

After finishing previous duty cycle next duty cycle begins. Thus if numbers of slots are equal mod T, where T – duty cycle duration, then sets of transmission in these slots are equal (look fig. 2). On figure 1 P_j - is a set of transmissions, done in slot, which number is equal to $j \bmod T$. Obviously $\bigcup_{j=1}^{T} P_j =$ ***P***.

Let's formulate conditions under which the transmission in slot is collision-free:

1. During the slot each sensor can be either source of message or receiver of message or be in sleep mode. This condition follows from technological features of components from which the sensor units are produced [3,4].
2. Each of the receiving sensor is to be in work range of only one transmitting sensor. This condition is obvious, cause otherwise there will be a mixture of signals of a few sensors, that is collision.

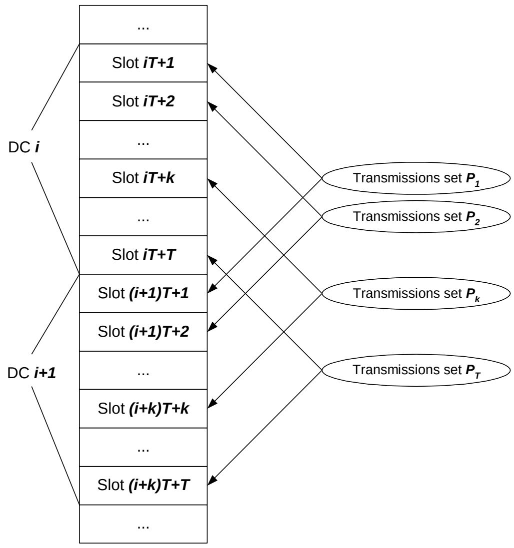

Figure 2 – Duty cycle structure

It is obvious that the problem of schedule calculation has various solves. We propose duty cycle duration as a criteria of different schedules comparison. The shorter duty cycle duration the more frequently information on BS updates. Therefore more frequent parameters of the environment can be controlled. Obviously, that minimal duration of duty cycle is N (it follows from the requirement, that BS cannot receive more than one message simultaneously).

III. Schedule for the network with topology "regular mesh"

Let's investigate important particular case of the network – the network with type «regular 2D mesh». Graph of such network is planar. All the cells of the mesh are regular polyhedrons with equal number of vertexes. Nodes of the mesh are sensors. There are three types of such meshes (see fig. 3): meshes, which cells are triangles (triangle meshes), rectangles (rectangle meshes), and hexagons (hexagonal meshes).

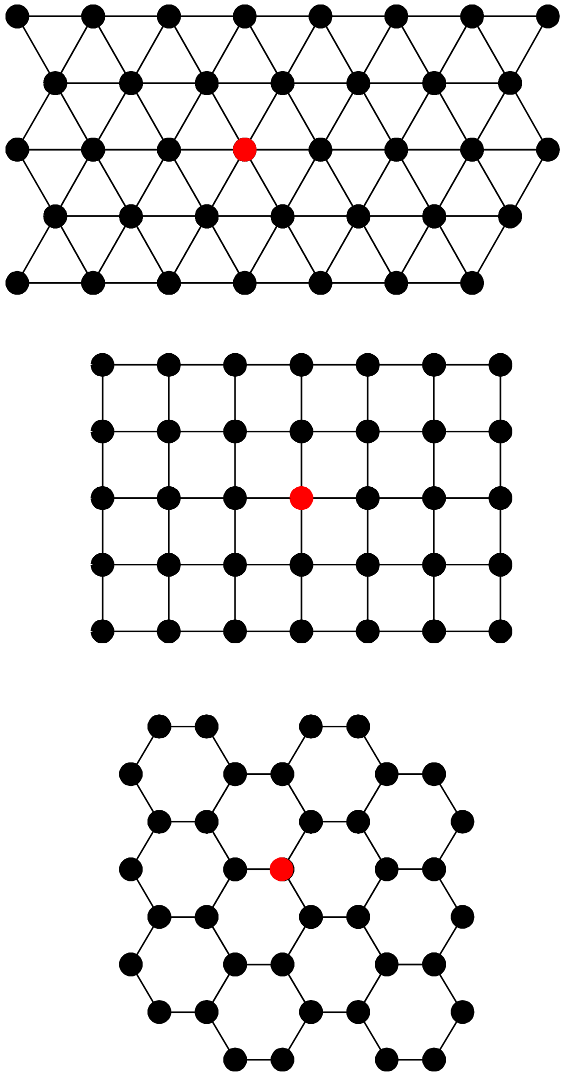

Figure 3 – Triangle, rectangle and hexagonal meshes. Black points are sensors, red points - BS.

Let's calculate the schedule for topology "triangle mesh". For the beginning auxiliary theorem is formulated.

Theorem

For every sensor network schedule with duty cycle duration $T \le 3N - 3$ can be composed.

Proof

For the proof we propose algorithm, which allows composing the schedule duty cycle duration 3*N*-3 for every sensor network.

Algorithm

All the messages are to be transmitted through the shortest way to BS. Lets choose the rout, which connects BS and the most distant sensor. Sensors on this rout are numerated in ascending distance from BS order. Sensors on this rout are split up into three sets. Set M_S ($s = 0,1,2$) contains sensors which distance from BS is equal to *s* mod 3. In first slot sensors from M_1 set transmit their messages, in second – sensors from set M_2, in third – sensors from set M_0

Let's show that in every slot transmission is collision-free. We use proof by contradiction. Suggest, that in some slot transmission, carried out by *(i+1)*-th sensor to *i*-th sensor crosstalk with transmission carried out by *(j+1)*-th sensor to *j*-th (*i* = *j* mod 3, *i* > *j*). This is possible only if *(i+1)*-th sensor is connected with *j*-th. It means that distance from *(i+1)*-th sensor to BS is not more than *(j+1)*, and *(j+1)<(i+1)*. So, not a shortest way was chosen. This contradicts to initial condition.

During first three slots the most distant sensor control of a route remains empty and is excluded from the active graph. Other sensor controls, receive on one message and transmit one MSG. BS gets one message. The network passes in a pseudo-initial condition. We name the given sequence of actions *iteration of algorithm* (IA), and three three, making it, we name *iteration steps* (IS).

After the first IA, next one begins. After (N-2) iterations (3(N-2) slots) BS gets N-2 message, and only two sensors remain in active graph. There are three types of graphs, consisting two sensors (see fig. 4).

In all three cases it is enough three slots for gathering remained messages. Than duty cycle duration is equal to $3(N-2)+3 = 3N-3$ slots. Q. e. d.

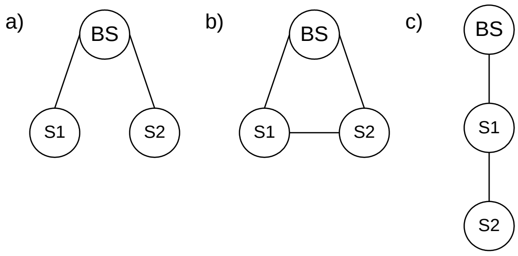

Figure 4 – Three types of graph containing three sensors

Messages in the given algorithm arrive on BS once a three slots, and the arrangement of steps in iteration can be chosen any way.

Now on the basis of the given algorithm we will formulate algorithm of drawing up of the optimum schedule for a network with topology «a triangular mesh». We will divide a network by means of six beams on 6 subnets (see fig. 5e). The sensors located on a beam, we will carry to subnet, located counter-clockwise concerning a beam. In any of subnets N/6 sensors are contained.

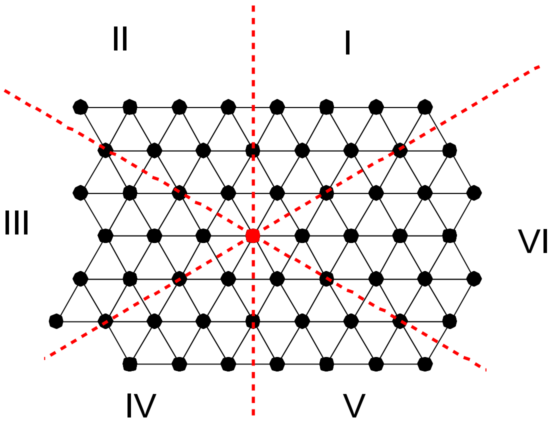

Figure 5 – Network division into 6 subnets

It is obvious that odd subnets are independent. Even subnets are independent either.

Let's make the schedule as follows. At the first stage we will make for odd subnets the schedule by the algorithm described above. As they contain 3(N/6) sensors it is required 3N/6 = N/2 slots for gathering all the messages from these subnets. For gathering of the information from the even subnets it is required N/2 either. Then duration of a duty cycle for a whole network with topology «a regular triangular mesh» will be equal to minimum possible - N.

IV Conclusion

In this paper we shown that for sensor network with topology «regular triangle mesh» schedule with minimal duty cycle can be calculated (number of slots in this duty cycle is equal to number of sensors in the network). Algorithm of such schedule calculation was proposed.

VI. References

1. Волхонский, В. В. Системы охранной сигнализации / В. В. Волхонский. СПб: Экополис и культура, 2005. 205 с.
2. Бакин Е.А., Евсеев Г.С. Яковлев В.Т. «Оценка длительности цикла работы в радиоканальной системе сбора данных с централизованным управлением» Вопросы Радиоэлектроники, сер. РЛТ, 2008. 202 стр.
3. http://www.efo.ru/cgi-bin/go?2532
4. www.electrosnab.ru/components
5. CC2500 Low-Cost Low-Power 2.4 GHz RF Tranciever. Datasheet. SWRS040B / Texas Instruments, 2007. 92 с.
6. Бакин Е.А., Евсеев Г.С. «Анализ времени сбора данных в системах контроля с древовидной структурой». Научная сессия ГУАП: Сб. докл.: в 3 ч. Ч. II. Технические науки. СПбГУАП. СПб., 2008. 197 стр.