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TRAFFIC ROUTING IN DISTRIBUTED WIRELESS COMPUTER NETWORKS

Annotation. Using the Lee wave algorithm, the intensity of traffic in the nodes of the central cluster of a distributed wireless network with the "star" topology is calculated. The modification of the algorithm is proposed, taking into account the speed properties of the channels. We determined analytically the average delay in data communication along the route depending on the intensity of traffic. The corresponding modification of the wave algorithm allowed us to obtain a more even distribution of the load across the nodes of the cluster.

Key words: wireless network, routing, load balancing.

Introduction. The intensive development of modern wireless technologies IEEE 802.11n, 802.11as, 802.11ax makes reasonable to use the broadband wireless connections for construction of the backbone part of distributed networks. In order to increase the productivity of such networks, as well as the reliability of their operation in the conditions of significant intensity of noise, promising directions are the introduction of topological redundancy (that is, standby routes), and the distribution of load between network routes. Routing technologies used in optical computer networks, with a hierarchy of predetermined routers (OSPF protocol) or defined in the routing information exchange (EIGRP protocol), for distributed wireless networks require significant modification.

Problem statement. The purpose of the work is to modify the wave routing algorithm for distributed wireless networks, taking into account the traffic intensity at the access points.

Main part. Routing protocols used in wireless networks are divided into protocols with proactive, reactive and hybrid routing [1].

In networks with proactive routing (TBRPF, FSR, and OLSR protocols), all paths in the domain are stored in the routing table of each node. When changing the topology, a broadcast update distribution

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is initiated that reflects these changes. These protocols provide a short recovery time, but generate a significant service traffic.

For reactive routing (AoDV, DSR, LMR, TORA, IARP, and IERP protocols), routes are formed for the time of data communication by broadcast updates distribution. The most widespread AoDV protocol uses the distance-vector method for paths metric calculation and the traditional form of routing tables. Reactive protocols considerably less than proactive affect to the network bandwidth, but present route information with a significant delay.

Hybrid protocols (ZRP, HSLS) for routing of near-zone nodes use proactive protocol, and for long-range nodes - one of the reactive protocols.

The use of an integrated routing algorithm for distributed wireless networks is suggested in [2]. It is based on the modified Lee wave algorithm. The main provisions are as follows. Node - source S assumes a zero distance, the wave index is zero. The wave propagates from S to all its neighbors and their distance relative to S is increased by 1 (hop). Accordingly, the wave index is also increasing. Each generated route is assigned a unique number and this number, in combination with the distance from S, is associated with the corresponding node - neighbor. If among the neighbors S the recipient of information D is determined, the operation of the routing algorithm ends on this, if not, then all nodes propagate the wave to their further neighbors. In this case, the neighbor of the wave distributed node is assigned an index equal to the current wave index +1. The route length is increased by one and its number is saved by the new node. After completing the search for all possible routes, the route with the least number of hops is determined, that is, the algorithm uses the distance-vector principle of choosing the optimal route. To illustrate the work of the algorithm and propose its modification, consider the central cluster of the trunk part of the distributed wireless network with the topology of the "star" (Fig. 1).

As the source S of the information to be transmitted, the access point AR1 is used here, and as the recipient of information D - AR6. The metrics of all possible routes from S to D are determined on the basis of the above-described wave algorithm. In Fig. 1, the corresponding distances are shown at the nodes of the cluster, and the brackets indicate the corresponding routes.

We will conduct a study of load distribution among the appointed cluster routes. By analogy the internal gateway routing protocols (IGRP, EIGRP), we assume that the traffic intensity for this route is inverse proportionally to its metric. The coefficient of equalization the cost of routes will be equal to d=2, which corresponds to the distance vector principle of forming the metrics of the routes $S \rightarrow D$ (the relevant metrics are shown in the left column of the figure). The intensity of traffic for the k-th route will be determined by the formula (1) [3]. According to (1), the intensity of traffic for the route with $M = 2$ is $I(M{=}2){=}0{,}1276$, analogously $I(M{=}3){=}0{,}0851$, $I(M{=}4){=}0{,}0638$. The intensity of full traffic $S \rightarrow D$ is taken equal to one.

$$I_k = \frac{1}{M_k} \cdot \frac{1}{\sum_{i=1}^{N} (1/M_i)}, \tag{1}$$

where M_k is the k-th route metric, N is the total number of routes $S \rightarrow D$ on condition d=2, M_i is the metric of the i-th route.

In this case, the intensity of traffic in the nodes of the cluster is:

$$I_2{=}0{,}4254;\ \ I_3{=}0{,}787;\ \ I_4{=}0{,}4254;\ \ I_5{=}0{,}4254. \tag{2}$$

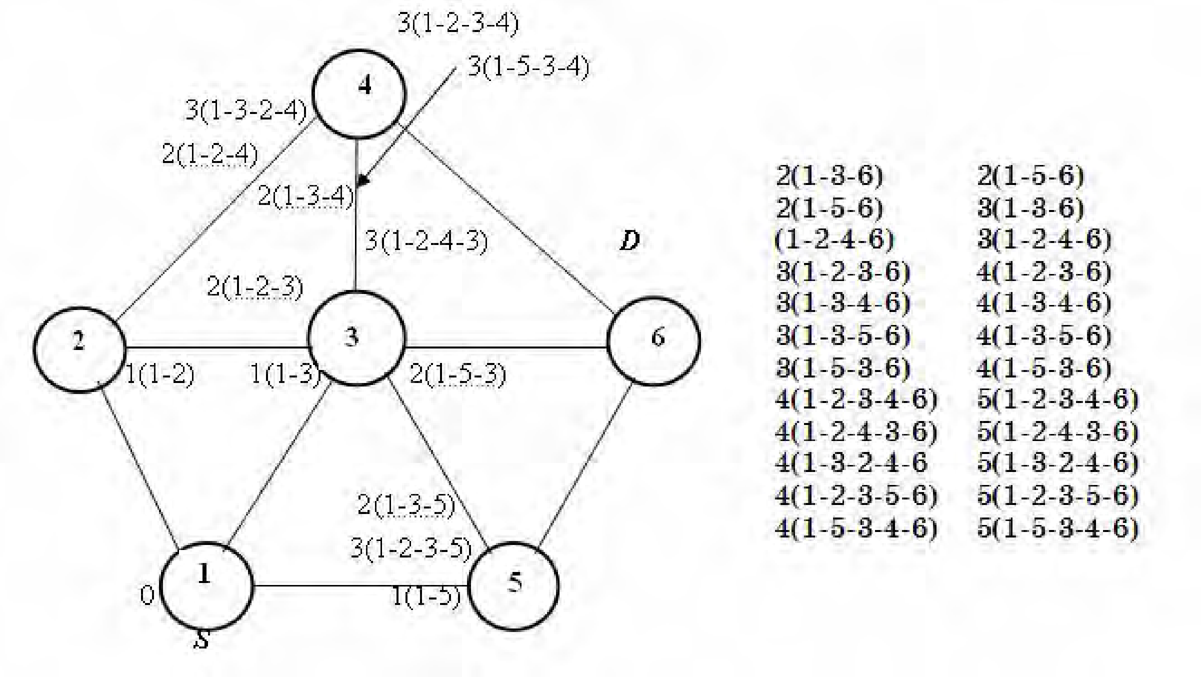

Figure 1 - Central cluster of the trunk part of distributed wireless network with "star" topology. The numbers in the circles are marked the access points

Let's analyze the possible changes of the cluster topology, which are characteristic especially for mobile wireless networks, when the access point located on the periphery of the cluster goes beyond the zone of stable radio communication.

Assume that the radio communication with AR2 has been lost. Then $I(M=2)=0{,}222$, $I(M=3)=0{,}148$, $I(M=4)=0{,}111$. The traffic intensity through the remaining nodes is:

$$I_3=0{,}777;\quad I_4=0{,}259;\quad I_5=0{,}629. \tag{3}$$

Assume that radio communication with AP5 has been lost. Then the intensity of the routes remains the same as in the previous case. The traffic intensity through the remaining nodes is:

$$I_2=0{,}629;\quad I_3=0{,}851;\quad I_4=0{,}629. \tag{4}$$

Comparing the results (2) with the results (3) and (4), it is necessary to note the following. In case (3), with a slight decreasing of the traffic intensity in the central node, nonuniformity of its distribution across the peripheral nodes increases significantly. In case (4), nonuniformity decreases, but there is a high traffic intensity in the peripheral nodes. This is dangerous when increased probability of loss of the communication with them. The modified coefficient of implicit load balancing [4], determined at the level of 0,5 from the maximum intensity, in case (3) is less than 100%.

We define the restriction of the distance-vector routing method used in the Lee wave algorithm. By calculating the metric using the number of hops over nodes, we do not take into account the high-speed properties of routes that are very sensitive to traffic intensity in wireless networks [5]. To analyze this, consider the technologies of packet traffic and switching channels, which when applied in wireless networks have their own peculiarities. So for packet switched networks, one of the main parameters is the average delay in data transmission. This parameter can be calculated as follows:

$$T_{av}=\frac{1}{N}\sum_{i=1}^{N}(t_i+p_i+q_i)\,, \tag{5}$$

where t_i is the time, which is necessary for the frame transmission to a neighboring device; p_i –total time of the frame movement in the input and output queues of the i-th node interfaces and frame processing; q_i – time, the magnitude of which determines the intensity of collisions on the input interface of the i-th node; N–total number of nodes.

For a network that consists of identical devices, time t_i weakly depends on the intensity of traffic. The dependence q_i is more complex.

The sub-level of the MAC access to the 802.11 environment assumes that the device can start transmission if the channel for transmission is free. The channel is considered to be free, if it does not display activity within a specified interval of time IFS (l_{IFS}), which begins after transmission of the frame. After the end of the IFS, if the channel is still free, this device waits for the delay time l_n, which consists of a random number of slots n. If the channel is left free after this, the transmission of the frame begins. Successfully received this frame, the recipient D sends the source of information S the confirmation frame ACK. If S has not received the ACK, he considers the sent information frame to be lost and repeats the transmission procedure with the specified modification. In particular, when re-transmission, the extended inter-frame interval EIFS is used and the l_n interval is increased. The number of slots defining the delay time l_n is selected from the set (0, ..., W-1) using equally probable distribution. The value of W, which is called a competitive window, depends on the number of attempts made to transmit this frame as $W=W_0*2^{m-1}$, where W_0 is the minimum competitive window used at the first attempt (m=1). In each subsequent attempt, the choice of l_n is limited to the pre-selected value below. In practice, for the first transmission W_0 = 32, and m is limited to 6.

Let's simulate the work of the described mechanism. Assume that the intensities of traffic generated by all of the network nodes are equal and is determined by the number of frames of standard length per unit time. The maximum number of nodes is limited to 10. We will increase the number of nodes n and fix the percentage of time r on the receiving interface of the access point AP, which is cumulatively occupied with receiving frames taking into account emerging collisions. We will assume that the probability of collisions is a quadratic function on the intensity of traffic. The calculations showed that the best approximation function $r=F(n)$ is the exponent $r=$ 0,0222exp(0,3269n), R^2=0,995. When a parabolic approximation, R^2=0,968. The value $q=r*\mathrm{T}_0$, where T_0 is a unit time interval. Thus, formula (5) can be represented as:

$$T_{av} = \frac{1}{N}\sum_{i=1}^{N}[t_i + (p_0 + p_S I_{ri}) + rT_0 \exp(vI_{ri})], \qquad (6)$$

where p_0 is the processing time of frames in a device that is constant in a network with identical nodes, p_{S} is an integrated parameter characterizing the speed of the frames moving in the queues of the input and output interfaces, v is the constant factor, I_{ri} is the relative intensity of traffic in the i-th node.

When transmitting traffic using a predetermined number of detached channels (switching channels) from S to D, for description of possible paths in [2] the parameter of the route weight is introduced as the sum of the weights of the nodes that belong to it. Under the weight of the node is understood the number of its neighbors. Let's assume that node A plans to start transmitting data to its neighbor, for example, node B. After the connection is established, the channel A to B will be occupied for the whole time of its existence. During this time, all neighbors of node B will not be able to start transmitting data to it using this frequency channel, as their signals will interfere with the main receiver signal of node B. The node A will not be able to receive data on the occupied frequency channel, as the signal emitted by this node will interfere with data reception. For this reason, it will be difficult to receive data the nearest neighbors of A.

Thus, an increasing the number of neighbors worsens the weight of the node and, accordingly, the entire route, and decreases its bandwidth. Therefore, the more universal characteristic, which implicitly takes into account and the number of neighbors, is the intensity of traffic through this node. With increasing traffic intensity, the delay time according to (6) increases and the bandwidth of the route decreases. We will analyze it on the example of the cluster, presented in Fig.1.

In accordance with (2), the intensity of traffic in node 3 is almost twice the intensity in nodes 2, 4, and 5. Therefore, we increase the wave index for node 3 twice. The corresponding route metrics are shown in the right column in Fig. 1. Equalization factor d=2,5. In this case, according to (1), the intensities of traffic for the corresponding routes are: $I(M=2)=0.158$, $I(M=3)=0.105$, $I(M=4)=0.079$, $I(M=5)=0.063$. Intensity in each node:

$$I_2=0,594,\ I_3=0,736,\ I_4=0,436,\ I_5=0,442. \quad (7)$$

The loading of routes became more uniform.

Conclusions

1. Using the Li - wave algorithm, the routes metrics for the central cluster of trunk part of the distributed wireless network with the “star” topology is calculated. On the basis of internal gateway routing

protocols methodology, we defined the intensity of traffic in the cluster nodes.

2. The necessity of wave algorithm modification is grounded taking into account the speed properties of the channels. For this case we determined the dependence of the average delay of data transmission along the route on the intensity of traffic. The wave index of the central node of the cluster has been corrected accordingly. This reduced the variations of traffic distribution.

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