INFORMATION MODEL OF VEHICLE TELEMATICS DATA CLUSTER COLLECTION USING UAV

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ABSTRACT

Telematics is a set of basic systems that provide services in accordance with user needs. Telematics systems can be classified according to the areas of tasks performed: monitoring the condition of the road, managing the flow of traffic, providing information services to road users, etc. Telematics also allows you to monitor the condition of vehicles or their cargo using remote monitoring methods and technologies. The use of telematic systems and technologies allows for real-time management of transport systems. The article is devoted to the development of an information model for collecting motor transport telematics data using unmanned aerial vehicles. A model of the V2R network type is considered in which one car in the cluster is defined as a central node that receives telematic information from other cars in the cluster and then transmits the collected information to the base station. It is proposed to replace the central vehicle with a specialized UAV that collects telematic information from all vehicles in the cluster and transmits the collected information to the base station. A formula has been obtained to calculate the maximum amount of information that can be collected and transmitted to the base station.

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KEYWORDS: *telematics, cluster, UAV, drones, optimization, information collection, base station.*

1 Introduction

As noted in [1], telematics is an ever-increasing element of complex integrated systems for performing certain transport tasks. Telematics is a set of basic systems that provide services in accordance with user needs. According to [2], telematics systems can be classified according to the areas of tasks performed, such as monitoring the condition of the road, managing the flow of traffic, providing information services to road users, etc. Telematics also allows you to monitor the condition of vehicles or their cargo using remote monitoring methods and technologies. According to [3], the use of telematic systems and technologies makes it possible to manage transport systems in real time.

As noted in [4], to achieve safety and productivity (performance), intelligent transportation systems are being developed, based on telematics and vehicle systems. To transmit data in telematics systems, wireless communications and network technologies such as IEEE 802.11 (WiFi), IEEE 802.16 (WiMAX), etc. are used. In intelligent transport systems, communications such as "vehicle-to-road" (V2R), and vehicle-to-vehicle (V2V). V2R communications include vehicle nodes and road base stations. This communication model can use WiFi, WiMAX and DSRC technologies. In particular, using DSRC technology (short range communication technology), each vehicle is equipped with an on-board unit (OBUS), which can receive or transmit information to road base stations [5]. It is possible that some OBUS create a group where all the information from nearby vehicles is first transmitted to one selected vehicle, which then sends all the collected information to the base station. The model of such cluster data transmission is shown in the diagram shown in Figure 1.

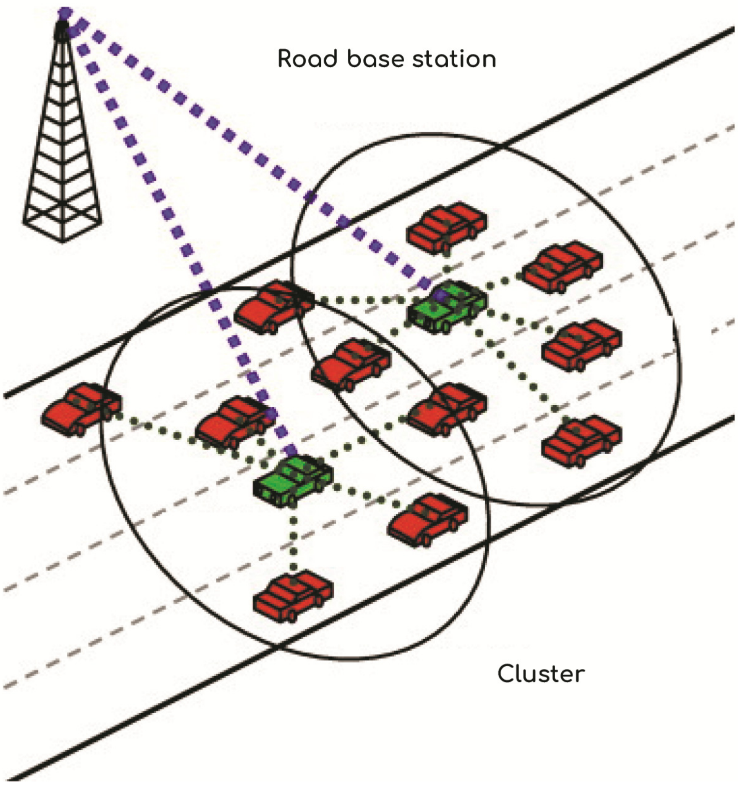

Fig. 1. Model of data transmission cluster organization in V2R networks

At the same time, it seems to us that using any car as a receiving unit for an entire cluster of cars is an impractical solution, because Some cluster of cars, passing near the next base station, must contain sufficiently reliable receiving and transmitting equipment. Moreover, due to the random nature of the occurrence of such clusters, almost all cars must carry such equipment, because any cluster element can be in the position of the central element of the cluster. To eliminate such inconveniences and excesses, a scheme can be proposed. Where the role of the central element of a certain cluster is performed by an unmanned aerial cluster data collection is shown in Figure 2 [6]. At the same time, as noted in [7, 8], UAVs can also be used as base stations.

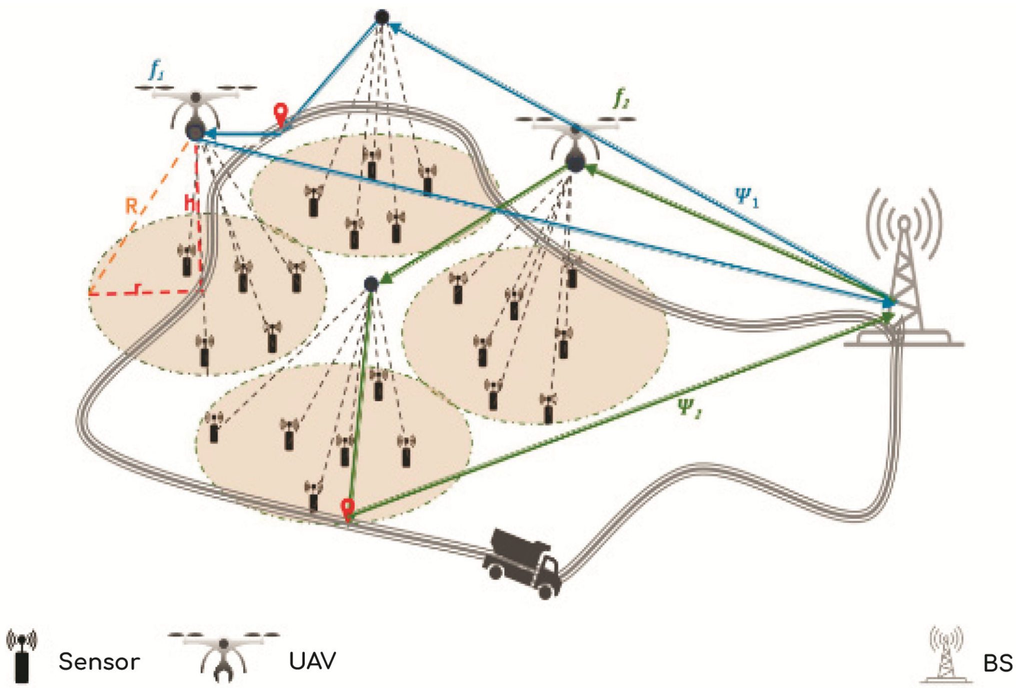

Fig. 2. Scheme of using UAVs to collect information from individual elements of a certain cluster [6]

It should be noted that in [6] it was analyzed in detail from the perspective of calculating energy consumption.

2 Materials and methods

Let's consider a two-stage data transmission model of the above-mentioned telematics system for transmitting and collecting data using UAVs as the central elements of clusters within which a wireless network is organized. A schematic representation of the bottom stage of a two-stage telematics network is shown in Figure 3.

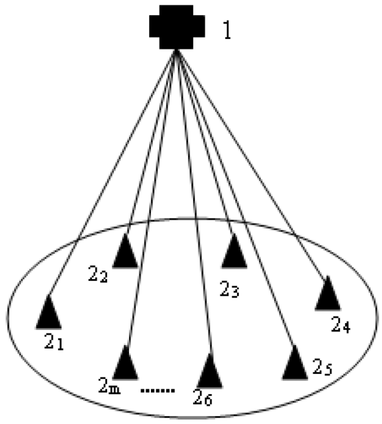

Fig. 3. Scheme of the lower stage of cluster data collection in a two-stage telematics system. The numbers indicate: 1 – UAV; $2_i; i = \overline{1,n}$ – transmitting nodes of cluster cars

The limit analysis and assessment of information flows in this scheme will be carried out on the basis of the classical Shannon formula and variational optimization methods. We define the amount of information transmitted from the i-th car to the j-th UAV as

$$M_{i,j} = N_{i,j} \cdot \log_2 \frac{I_0}{\sigma_j} \quad (1)$$

where $N_{i,j}$ – number of pulses whose amplitude can have one of I_0/σ_j number of positions, where I_0 – the maximum possible signal amplitude; σ_j – UAV receiver noise.

If we take into account that all the cars on the road dynamically form a certain cluster, then in order to obtain reliable spatio-temporal information it is necessary to maintain simultaneous parallel communication with all cars. In this case, if we take into account that the number of pulses in the information message from a specific car to the UAV depends on the controlled parameters of the car, then we can assume that the total noise during data transmission of the *i*-th car will depend on $N_{i,j}$. Consequently, formula (1) takes the form

$$M_{i,j} = N_{i,j} \cdot \log_2 \frac{I_0}{\sigma_j(N_{i,j})} \quad (2)$$

Further, if we assume that in each randomly selected cluster *j* the set of cars is such that their indicators $N_{i,j}$ form an ordered set N_j, where

$$N_j = \{N_{1,j}; N_{2,j}; N_{3,j}; \ldots N_{m,j}\} \quad (3)$$

in which $N_{i,j} = N_{i-1,j} + N_j$; $i = \overline{1,m}$; $N_{0,j} = 0$.

Therefore, we define the amount of information transmitted from one *j*-th cluster to the *j*-th UAV as

$$M_j = \sum_{i=1}^{m} N_{i,j} \cdot \log_2 \frac{I_0}{\sigma_j(N_{i,j})} \quad (4)$$

At the same time, it can be required that the total noise when connecting all cars does not exceed the value of C_1. Therefore, we have

$$\sum_{i=1}^{m} \sigma_j (N_{i,j}) dN_{i,j} = C \,; \;\; C = const \tag{5}$$

As a first approximation, we write discrete models (4) and (5) in continuous form. We rewrite model (4) as

$$M_{jm} = \int_0^{N_{j\max}} N_j \cdot \log_2 \frac{I_0}{\sigma_j (N_{i,j})} dN_j \tag{6}$$

Let us represent model (5) in continuous form as

$$\int_0^{N_{j\max}} \sigma\left(N_j\right) dN_j = C \tag{7}$$

Based on models (6) and (7), we create a variational optimization problem whose objective functional F1 has the form

$$F_1 = \int_0^{N_{j\max}} N_j \cdot \log_2 \frac{I_0}{\sigma_j (N_{i,j})} \; dN_j + \lambda \left[\int_0^{N_{j\max}} \sigma(N_j) dN_j - C \right] \tag{8}$$

where λ – Lagrange multiplier.

According to [9], the solution to problem (8) must satisfy the condition

$$\frac{d\left\{ N_j \cdot \log_2 \dfrac{I_0}{\sigma_j (N_{i,j})} + \lambda (N_j) \right\}}{d\sigma\left(N_j\right)} = 0 \tag{9}$$

From condition (9) we obtain

$$\frac{N_j}{C_1} \cdot \frac{1}{\sigma_j (N_j)} + \lambda = 0 \tag{10}$$

where C_1 – constant for converting binary logarithm to natural logarithm.

From (10) we obtain

$$\sigma_j (N_j) = - \frac{N_j}{\lambda C_1} \tag{11}$$

Taking into account (7) and (11) we find

$$- \int_0^{N_{j\max}} \frac{N_j}{\lambda C_1} \; dN_j = C \tag{12}$$

From expression (12) we have

$$\lambda = -\frac{N_{j\max}^2}{2CC_1} \tag{13}$$

Inserting (13) into (11) we get

$$\sigma_j(N_j) = \frac{2CN_j}{N_{j\max}^2} \tag{14}$$

When solving (14), the functional *F*1 reaches a maximum, since the derivative (10) with respect to $\sigma_j(N_j)$ turns out to be a negative value.

Taking into account (6) and (14), it can calculate the maximum value M_{jm}, i.e.

$$M_{jm,\max} = \int_0^{N_{j\max}} N_j \cdot \log_2 \frac{I_0 N_{j\max}^2}{2CN_j}\ dN_j = \frac{N_{j\max}^2}{2} \log \frac{I_0 N_{j\max}^2}{2C} +$$

$$\int_0^{N_{j\max}} N_j \cdot \log_2 \frac{1}{N_j}\ dN_j \tag{15}$$

Having designated

$$\int_0^{N_{j\max}} N_j \cdot \log_2 \frac{1}{N_j}\ dN_j = C_2$$

Let's write

$$M_{jm,\max} = \left[\log \frac{I_0 N_{j\max}^2}{2C}\right] \frac{N_{j\max}^2}{2} + C_2 \tag{16}$$

Thus, the maximum amount of information coming from one cluster to the input of the base station can be estimated using formula (16).

3 Discussion

A cluster model for collecting telematic information transmitted to a base station is analyzed. A model of the V2R network type is considered in which one car in the cluster is defined as a central node that receives telematic information from other cars in the cluster and then transmits the collected information to the base station. It is proposed to replace the central vehicle with a specialized UAV that collects telematic information from all vehicles in the cluster and transmits the collected information to the base station. A variational optimization problem was compiled, the solution of which made it possible to determine the maximum amount of information that can be collected and transmitted from one cluster to the base station.

4 Conclusion

1. An information model of a cluster type for collecting and transmitting telematic information from one cluster has been constructed.
2. In relation to the V2R network model, it is proposed to replace the central vehicle of the cluster with a UAV, which performs the function of collecting and transmitting telematic information to the base station.
3. A formula has been obtained to calculate the maximum amount of information that can be collected and transmitted to the base station.

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