Performance Evaluation of Three Layer Vehicular Network

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Introduction

In due time vehicular wireless network is made using the IEEE 802.11p standard. This standard enables a wireless access to vehicular environment. 802.11p functions in the 5.9 GHz range; this technology permits access to navigational options, multimedia information and also telemetry. For creation of a wireless network that would work by 802.11p standard, more expensive equipment is required than for other IEEE wireless network standards.

Three layer Vehicular Network Model

This article offers to create a vehicular wireless network using a three layer wireless network model.

The terminal count in each vehicular wireless network is usually high. On evaluation of bandwidth it is possible to replace conveyor transfer of files with a consistent transfer. Thus, neglecting the intervals t_r^w between incoming response packets, we get a closed exponential model (Fig. 1).
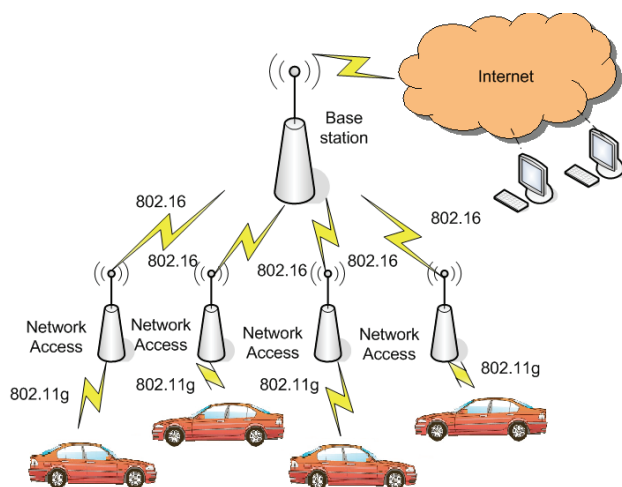

Fig. 1. Three layer Vehicular Network with PCF

DCF control functions are the mechanism of access to the wireless environment used in the 802.11p protocol. As a possible setting over DCF, the PCF central control functions are used. DCF model has a high efficiency, while the network load is low. However the performance significantly drops as the amount of terminals and the load increases, which is linked with a high probability of collisions and an increased delay spans. The alternative control mechanism PCF permits to solve these problems, because it works in conditions lacking concurrency, which permits to provide a much higher bandwidth maximum than DCF.

PCF represents a TDMA model, where network working time is divided to inquiry cycles, consisting of frequent slots of altering length. Slot j is meant to exchange frames between terminals and j-th terminal. Unlike a terminal that controls a single packet line, terminals controls N operations of terminals, where N – the amount of inquired terminals. With a PCF model, the base station controls several lines (Fig. 2) [1, 2].
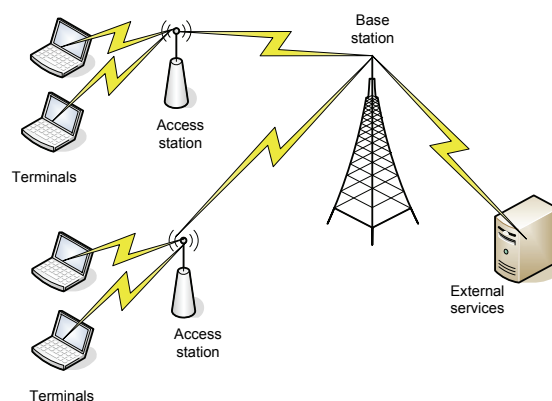

Fig. 2. Model of wireless network with a central control

For performance evaluation of a three level network, the performance for every node of this network must also be evaluated. In the given network, vehicle speed plays a large role in network performance.

Terminal connections of fringe stations and vehicle speed, has a large impact on the vehicular wireless network.

A special troughput is used for evaluation of data transfer rate. A series of experiments were performed where the speed of mobile stations were altered. The Chariot program permits to observe the data transfer rate, as a function of the time of the start of the measurement. Knowing the time and movement speed of a mobile object, the time was recalculated to distance. The resulting function can be seen in the Fig. 3.
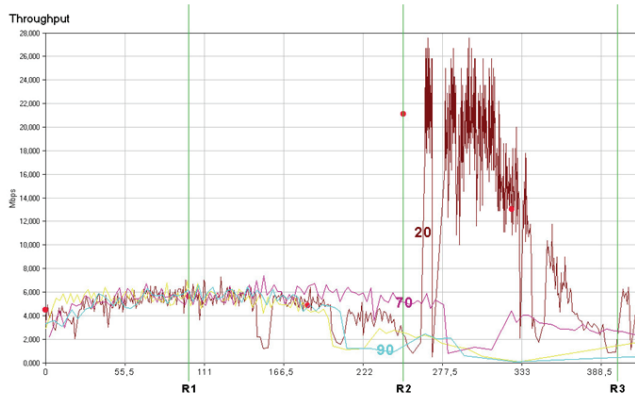

Fig. 3. Data transfer rate as a function of location of the mobile object, during its movement at speeds of 20km/h, 60kkm/h, 70km/h and 90km/h

As there is a relation between data transfer rate and signal to noise ratio, let's try to find the conversion quotients. These quotients will show how the variables of equation are related among themselves. Let's observe this trough an example of an object's movement at speed of 20km/h. For this we will divide each result to three stages. Each stage is connected with a particular router and has and has an increasing character at first, then peaks (maximum value), and then drops. Each part lasts approximately 10 seconds at velocity of 20km/h. We will then find the quotients using the following formula

$$\alpha_{11} = \frac{\overline{S/N}}{\overline{\eta}}, \qquad (1)$$

where $\overline{S/N}$ - the average signal to noise ratio for 10 seconds, but $\overline{\eta}$ - the average bandwidth for 10 seconds. As a result we will get a following table with recalculation quotients (Table 1).

Table 1. Recalculation quotients for data transfer rate and signal to noise ratio

	AP1		
Signal to noise ratio	30,7	44,5	38,9
Data transfer rate	4,3395	5,5337	5,6095
α	7,074548	8,041636	6,934664
	AP2		
Signal to noise ratio	33,2	44,9	38,1
Data transfer	3,8441	9,484	5,6322

	AP1		
rate			
α	8,636612	4,734289	6,764675
	AP3		
Signal to noise ratio	38,4	45,6	32
Data transfer rate	2,7162	2,8574	2,7335
α	14,1374	15,95856	11,7066

The theoretical bandwidth of any data channel is calculated using the Shannon's formula. If signal occupies the bandwidth line F and the relation of signals capacity's is Pc/Pm, then the maximum amount of transmittable data per second, with any chosen error rate is the value

$$C = F \log_2 (1 + P_c / P_m). \qquad (2)$$

It must be remembered that in the formula the equitation S/N - P_c/P_m - is shown in times. Therefore the variables in dB must be recalculated in times: $xdB = 10 \lg \frac{P_c}{P_m}$; from this $\frac{P_c}{P_m} = 10^{x/10}$. From the table 1. it can is evident that Shannon's formula with a direct recalculation of signal to noise ratio to data transfer rate is impossible for use in networks with mobile objects.

To find the conversion probability, we will find the approximating functions for the first stage of signal to noise ratio (Fig. 4) [3].
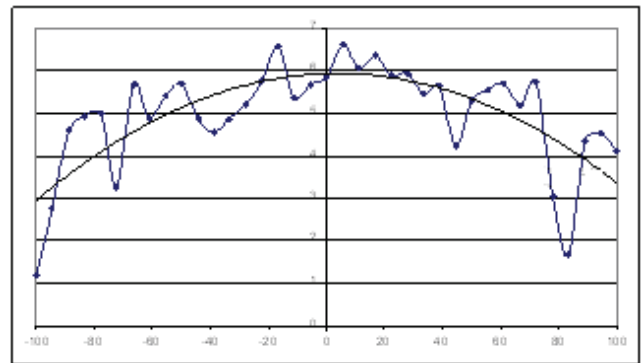

Fig. 4. Data transfer rate in a wireless network as a function of distance till router and the approximating function

Bandwidth equation for a three layer network:

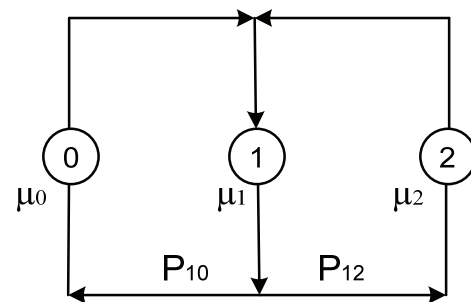$$X_1 = \frac{\mu_0}{\mu_1 P_{10}}; \quad X_2 = aX_1; \quad a = \frac{\mu_1}{\mu_2} P_{12}. \qquad (3)$$

Fig. 5. Three layer Network model

Starting point for the calculation is the normalizing function G(N), that is chosen from the principle of the sum of probabilities being one. $p(n_0, n_1, n_2)$, where n_i in vector $\bar{n} = (n_1, n_2, n_3)$ is the inquiry count in $i-th$ node. The resulting equation for G(N) calculation looks like this:

$$\begin{cases} G(N) = \sum_{\bar{n}} \prod_{i=1}^{3} (X_i)^n i, \\ \bar{n} \in \left\{ (n_1, n_2, n_3) / \sum_{i=1}^{3} n_i = N, n_i \geq 0 \forall_i \right\}. \end{cases} \quad (3)$$

Function for the studied three layer vehicular network

$$G(N) = \frac{1}{1-a} \sum_{j=0}^{N} X_1^j \left(1 - a^{j+1}\right). \quad (4)$$

Performance η of the three layered network is defined as the count of processed inquiries in a unit of time. The finished task is put out trough the subsystem of input/output, and instantly trough it a new task is loaded. The output flow is equal to input flow and from this rule of flow balance it is possible to write

$$\eta = \mu_0 \left(1 - p\{n_0 = 0\}\right). \quad (5)$$

Probability of a lack of inquiries in i-м node

$$p\{n_i = 0\} = \frac{G(N) - X_i G(N-1)}{G(N)}. \quad (6)$$

By inserting in (3) the variable G(z) from (1) and by moving on to (2), we get the result of

$$\eta = \frac{\left(1 - X_1^N\right)\left(1 - aX_1\right) - a\left(1 - (aX_1)^N\right)\left(1 - X_1\right)}{\left(1 - X_1^{N+1}\right)\left(1 - aX_1\right) - a\left(1 - (aX_1)^{N+1}\right)\left(1 - X_1\right)} \mu_0. \quad (7)$$

Performance evaluation of IEEE 802.11g MAC protocol

The 802.11g standard uses a frequency range of 2.4 GHz, providing a transfer rate of 54 Mbit/s. Because the size of the antennas used to transmit and receive signals depends on the frequency, for antennas with similar characteristics there is a frequency dependent effect on the reduction in signal strength as measured by two antennas. This effect is commonly referred to as frequency dependent path loss.

802.11g mandates the use of a 20 µs slot time. The use of a 13 µs slot time as is used in 802.11p is optional. Only 802.11g modulation (OFDM) will be used, restricting associations to 802.11g clients. Therefore, the short slot time of 9 µsec will be used and the only preamble that will be relevant is the OFDM preamble. And, finally, there is no need for a protection mechanism because the traditional 802.11 medium access mechanisms will manage the sharing of the wireless media. This is the configuration that will provide the maximum throughput for 802.11g devices

because, as described above, there are no throughput degradations caused by long slot times, 802.11b devices, or protection mechanisms[4].

The count of workstations in network are designated through M. Intensity of queries from our station to the access point are designated through λ. Service intensity of queries we will designate through μ.

According to this model the network performance is expressed as

$$\eta = (1 - p_0)\mu, \quad (8)$$

where p0 is probability that the system has not requests for service.

The bandwidth of a single stage will be

$$\eta = (1 - p_0)\mu/M, \quad (9)$$

where M is count of workstations in the network ($M \geq 2$).
In this model

$$p_0 = \left[\sum_{k=0}^{M} \frac{M!}{(M-k)!} \left(\frac{\lambda}{\mu}\right)^k \right]^{-1}. \quad (10)$$

Dependence of point performance in the dependence from count of workstations

$$\eta_1 = f(M). \quad (11)$$

Performance evaluation of IEEE 802.16 MAC protocol

IEEE 802.16 architecture consists of two kinds of fixed (non-mobile) stations: subscriber stations (SS) and a base station (BS). The BS regulates all the communication in the network.

We assume that there are N SSs in the system and BS broadcasts a back-off window size B. Since each user will choose between 1st and Bth reservation slots to send its bandwidth reservation, the probability of choosing a given slot is p=1/B. As a result, the probability of a given slot that is not selected by any SS is given by

$$P_{NS} = (1 - p)^N. \quad (12)$$

Probability of a successful broadcast equals to the probability that one user will choose the given slot. Therefore the system performance is calculated by formula [5]

$$P_{th} = Np(1 - p)^{N-1}. \quad (13)$$

To maximize system throughput, we have to get:

$$\frac{dP_{th}}{dp} = N(1 - p)^{N-1} - N(N-1)p(1 - p)^{N-2} = 0, \quad (14)$$

$$P = \frac{1}{N}, \quad (15)$$

$$p = \frac{1}{B} = \frac{1}{N} \Rightarrow N = B. \quad (16)$$

Conclusions

In the given work presents a three layered model of a vehicular wireless network. A calculation of bandwidth for each node of three layer network was explained. In article, it was explained how the vehicle speed influences the bandwidth of a vehicular wireless network. A significant gain in bandwidth by using the 802.11g standard was demonstrated.

Another significant gain in bandwidth was demonstrated by using central control in mechanical channel.

In the given article a method of performance calculation for three layer network model was described. In the future our laboratory will research a multipath three layer network model and a change of signal volume.

References

1. **Вишневский В. М., Ляхов А. И., Портной С. Л., Шахнович И. В.** Широкополосные беспроводные сети передачи информации. – Техносфера, 2005. – 592 с.

2. **Вишневский В. М.** Теоретические основы проектирования компьютерных сетей. – Техносфера, 2003. – 512 с.

3. **Ipatovs A., Petersons E**. Performance Evaluation of WLAN depending on Number of Workstations and Protocols // Electronics and Electrical Engineering. – Kaunas: Technologija, 2006. – No. 8(72). – P. 15–18.

4. **Dong–Hoon Cho, Jung–Hoon Song, Min–Su Kim, and Ki–Jun Han.** Performance Analysis of the IEEE 802.16 Wireless Metropolitan Area Network // First International Conference on Distributed Frameworks for Multimedia Applications. – IEEE Computer Society, 2005. – P. 130–136.

5. **Tianlin Wang Refai, H.H**. Network performance analysis on IEEE 802.11g with different protocols and signal to noise ratio values // Wireless and Optical Communications Networks Second IFIP International Conference. – USA: 2005 – P. 29–33.

E. Petersons, N. Bogdanovs. Performance Evaluation of Three Layer Vehicular Network // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 6(112). – P. 25–28.

IEEE 802.11x is the new standard for communication in a wireless LAN. Despite these differences, 802.11 is required to appear to higher layers (LLC) as a traditional 802 LAN. When assessing the performance of a wireless LAN, it is especially important to consider how this LAN will be used. When analyzing wireless networks, there arises a need to evaluate the whole network or a part of it. Whole Vehicular network, discussed in this work, consist of three layer networks. When analyzing wireless networks, the theory of queues net is used. During the research involving analytical methods, wireless network performance characteristics of various types were assessed. In the result of the experiment, the mathematical models for three layer wireless networks were selected as ones who are to be used for choosing an optimal method for performance evaluation of Short range communication Vehicular network. . Ill. 5, bibl. 5, tabl. 1 (in English; abstracts in English and Lithuanian).

E. Petersons, N. Bogdanovs. Trijų lygmenų transporto protokolo našumo įvertinimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 6(112). – P. 25–28.

IEEE 802.11x – naujas standartas, reglamentuojantis informacijos perdavimą belaidžio ryšio tinkle. Norint nustatyti tokio ryšio našumą, reikia žinoti, kokiam tikslui tokia sistema bus taikoma. Darbe analizuojamas transporto protokolas, sudarytas iš trijų lygmenų. Tyrimo metu taikant analizės metodus, buvo nustatytos belaidžio ryšio našumo charakteristikos. Iš gautų eksperimento rezultatų buvo atrinkti matematiniai modeliai, skirti optimaliam metodui parinkti. Il. 5, bibl. 5, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).