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RADIO TECHNOLOGIES IN CUSTOMER'S ACCESS NETWORKS

Summary of Doctoral Dissertation
Technological Sciences, Electrical and Electronic Engineering – 01T

1021

Vilnius „Technika“ 2004

VILNIUS GEDIMINAS TECHNICAL
UNIVERSITY

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VILNIAUS GEDIMINO TECHNIKOS
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Arūnas Šaltis

**RADIJO TECHNOLOGIJOS VARTOTOJŲ
PRIEIGŲ TINKLUOSE**

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1. INTRODUCTION

Motivation of the thesis

The liberalization of telecommunication market, which is unrolling rapidly these days, brings out more and more new providers of services. Although the previous monopoly holders telecom' still predominate in customers' access networks and receive only moderate strife from new members of the market. That allows them to sustain the high level of rental payments. If the new comers are not willing to rent the communication channels, they ought to wire new communication lines. However this is acceptable only in case of densely populated area, where the number of subscribers is high. In contrary way, the investment would be pointless. In the less populated areas the wireless access network is a much-welcomed alternative. Unfortunately, despite the fact that the special equipment and appropriate frequency range were arranged for the use of those wireless access networks, they are not very attractive because of high implementation price. In the recent past a new way of communication networks was found, that is wireless local access networks, like IEEE 802.11 or ETSI HiperLAN that is most suitable in the given situation.

A detailed analysis on technologies, which are designed for implementation in the densely populated urban areas for high-speed communication, is not carried yet. And that is an important reason for creating such a doctoral dissertation, for promoting the research works on alternative way to apply existing communication technologies. In the future this dissertation may be the ground for creating regional expansion of information systems after Lithuania's integration in European Union.

The objectives and tasks

The aim of this work is to analyze the modern radio communication technologies and to formulate a methodology and means for implementing them in customers' premises networks.

It was necessary to solve these tasks:

1. to analyze standard wireless communication devices, to create a methodology for investigation of their capabilities to function in customers' access networks within non-typical conditions;
2. to examine by experiments the means of wireless radio communication that function in non-licensed frequency and to determine the main parameters;
3. to analyze the methods of voice coding and specify the data traffic models that are created by voice;

4. to investigate the data traffic that are created by customers' technologies and to select the appropriate models for them;
5. to create the methodology and the means for rational application of wireless communication technologies in customers' premises networks.

Scientific novelty and utilization of results

Now days in the world there are done many works in the field of consumers' access optimization and creation of new technologies and protocols. The mechanisms of standard LAN and WLAN are examined and adapted to typical conditions of data transferring when network has a clear defined infrastructure or when it has not (*ad hoc* version). In this work the research object is atypical network, created on the ground of LAN and WLAN mechanisms, called customers' premises network (CPN).

The main elements of novelty presented in this work:

1. introduction of alternative category of customers' premises network running on the ground of non-licensed frequency radio communication devices;
2. experimental examination of IEEE 802.11a/b standard devices in Lithuania;
3. determination of correlation features between voice speech-silence intervals;
4. proposal and examination of joint voice and data multiplexing protocol for efficiency rising with the help of radio communication channel of limited throughput.
5. proposal of costumers' premises network and the criteria of their estimation.

The results that are performed in this work may be addressed directly to creation and implementation of PCN or other networks, based on IEEE 802.11 standard and IP technologies. The proposed packets multiplexing algorithm may be also implemented in the networks, where it is a high level of overhead of packets headers.

For the defense are presented:

6. methodology of IT estimation;
7. experimental examination of IEEE 802.11 protocol;
8. adjusted model of voice speech-silence intervals;
9. algorithm for packets grouping.

Approbation of the research and publications

The results of this work were presented in eleven reports and discussed at nine technical conferences:

1. In the conf. of Young scientists "Lithuania without science – Lithuania without future" in Vilnius in 2000, 2001 and in 2002.
2. In the conf. „Electronics’2001” and „Electronics’2002” in Kaunas in 2001 and in 2002.
3. In the int. conf. “16th International Wroclaw Symposium on EMC” and “17th International Wroclaw Symposium on EMC” in Wroclaw in 2002 and in 2004.
4. In the conf. „Electronics’2003” and „Electronics’2004” in Vilnius in 2003 and in 2004.

The material of the dissertation was published in 8 scientific publications: 4 of them in appreciable technical magazines.

The structure and the scope of the work

The work is written in Lithuanian. It consists of 6 chapters, list of references, and 1 appendix. There are 147 pages of text, 16 tables, 107 figure, and 191 bibliographical sources.

2. RADIO TECHNOLOGIES IN CUSTOMER’S ACCESS NETWORKS

This chapter presents the review about wireless local access network (WLAN) as an alternative to wired communication devices in the densely populated areas. The analysis has shown that mean time in the sphere of fixed premise networks the most applicable are the devices of IEEE 802.11b standard, but in the near future the devices of IEEE 802.11a/g standard should be used instead. However this device is not designed for services oriented to connections, so if there is a need to implement it in CPN effectively, a new methods should be found for sustaining a satisfactory level of quality while using resource of radio channel.

3. CUSTOMERS’ PREMISES NETWORKS BASED ON WLAN

In this chapter a definition of customer’s premises networks as a new category of access networks is defined. In CPN the customers create networks on their own by themselves. These features may describe CPN:

1. CPN is the last chain between PSTN and Internet networks and customers’, it contributes integrated telephone and internet services;
2. the architecture of CPN is mixed, and its topology is ad hoc. The devices are also mixed, though the dominancy of radio communication prevails. The most applicable standards are IEEE 802.3, IEEE 802.11 a/b/g, IEEE 802.16;

3. for data and voice transmitting in CPN it is recommended to use the stack of TCP/IP protocols because it is the simplest and most popular form of transmission that links CPN with Internet;
4. the creation of CPN is based on the principle of territory or belonging-affinity.

The object of this research is an area of a number of suburban of relatively small towns, settlements, or steadiness, where the concentration of radio communication devices is not high and where is almost no interference.

The examination of CPN was carried out on basis of devices that are characteristic for IEEE 802.11a/b/g standard. That is because:

1. qualitative and uncostly radio communication devices are already created;
2. radio spectrum, used by above mentioned devices, is free for utilization;
3. technical potentiality of the devices is high, and for this reason is it is possible to create systems for various purposes.

While analyzing the adjustment of IEEE 802.11 standard WLAN for CPN, a mathematical model of WLAN was developed. One of the objectives of this analysis was to calculate the maximum throughput of the network. The experiments show that throughput is very dependable from the size of the packets that are being transmitting (Fig 1). In the case when the size of the packet is equal 64 bytes and the throughput of physical channel is 11 Mb/s the transmission rate is not more than 0,5 Mb/s.

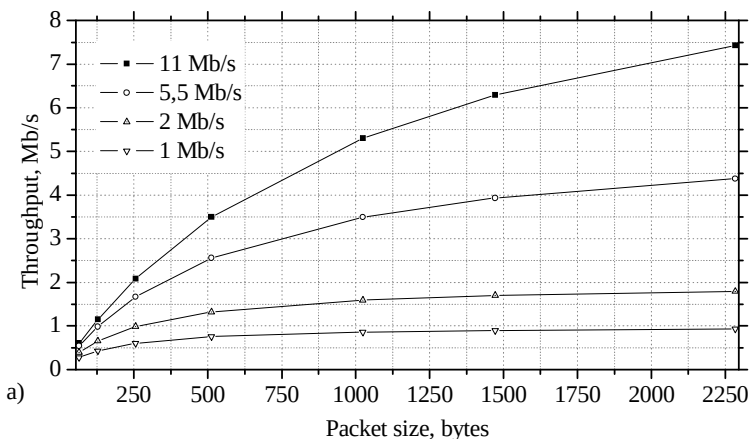


Fig. 1. The dependence of network throughput in IEEE 802.11b on packet size
1 pav. Tinklo laidumo priklausomybė nuo paketo dydžio

The other objectives of the research on possibilities of IEEE 802.11b standard devices to be applicable in CPN are as follow:

1. to examine the characteristics of data transmission rate and it's dependence from frequency range and the number of stations;
2. to ascertain the mutual effects of the channels that function in 2,4 GHz frequency range and their impact on the work of devices;
3. to examine the dependence of errors from the size of the packets or signal-noise ratio.

Experiments show that there are several dependences of transmission rate and other variables. First of all transmission rate depends on the number of intermediate stations. A consistent pattern of transmission rate reduction $1/(n-1)$, when n – a number of stations, was experienced. Secondly, transmission rate depends on higher-level protocol. It was stated that TCP traffic is transmitted by the maximum transmission rate of 5 Mb/s and UDP traffic by 6 Mb/s.

The dependence of data transmission from mutual interferences is shown in Fig. 2. It was determined that when the distance between station is short, the central channel frequencies often may be remoted less than 15 MHz. That means that when the distinction of central channel frequencies is less than in the regulated standard, the specification of protocol does no impact on transmission rate. When the distinction of central channel frequencies is less than 10 MHz, but not equals zero, then one of the pairs is not able to discern from the noise around a signal of a near by working pair. This involves additional interference that in turn influences the reduction of signal-noise ratio (Fig 3.). This is also the same reason for reduction of transmission rate.

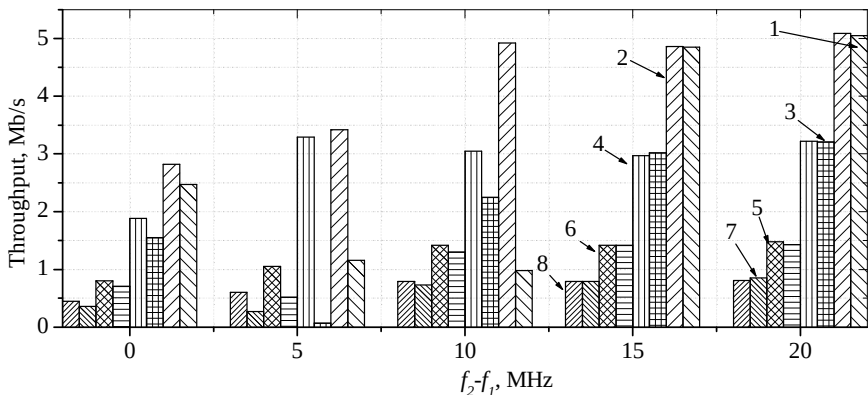


Fig. 2. The dependence of data transmitted by TCP protocol transmission rate on the distinction of channel frequency $f_2 - f_1$. 1,2 – 11 Mbps; 3,4 – 5,5 Mbps; 5,6 – 2 Mbps; 7,8 – 1 Mbps pairs.

2 pav. Informacijos perduodamos TCP protokolu spartos priklausomybė nuo kanalų dažnio skirtumo $f_2 - f_1$. 1,2 – 11 Mbps; 3,4 – 5,5 Mbps; 5,6 – 2 Mbps; 7,8 – 1 Mbps poros.

The qualitative measurement of channel has shown that the frequency of missing packets does not depend on the size of the packet, but it depends on the signal-noise ratio. Long-term examination leads to predication that in the distant areas the (ratio) between signal and noise remains almost unvaried (Fig 4.). That means that customers' networks WLAN based on the ground of IEEE802.11b is likely to function steady.

4. VOICE AND DATA TRANSMISSION IN CPN

Data traffic examination

The analysis of data traffic is well expatiated in scientific literature, but it concentrates mainly on the traffics of backbone, leaving the examination of

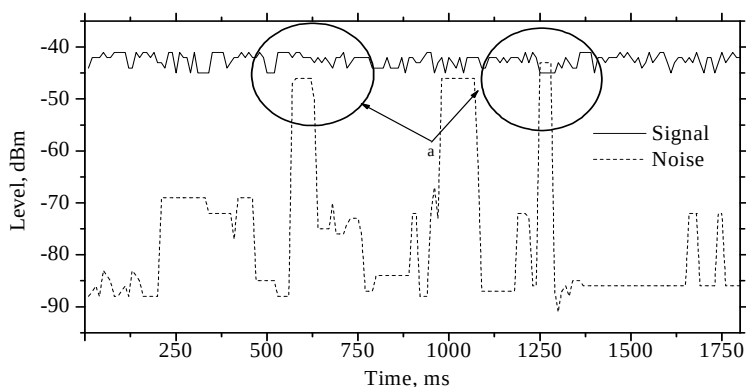


Fig. 3. The change of signal and noise: a – increase of noise
3 pav. Signalo ir triukšmo pokyčiai: a – triukšmo padidėjimas

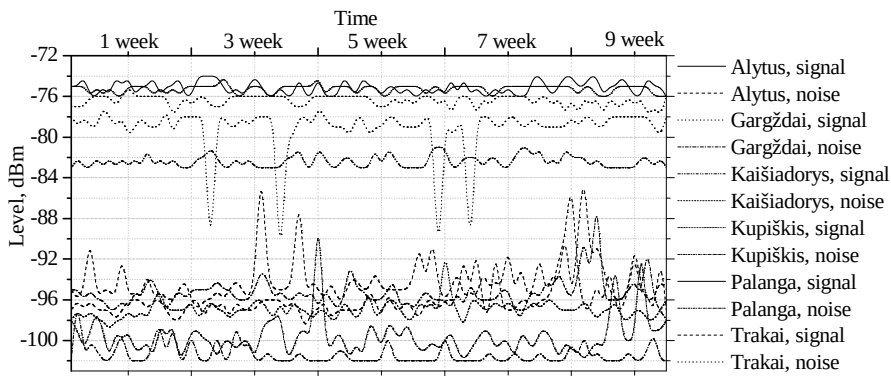


Fig. 4. The levels of signal and noise in the long period run
4 pav. Signalo ir triukšmo lygiai ilgame laiko periode

small customers' groups traffic aside. For this reason the measurement were carried out in one of the points of Litnet networks and in one network of Lithuania's ISP, where at the same time internet was used by not more than 100 customers.

Pending the experiments the statistics of around 200 millions packets were collected. According to them, 50 % of packet traffic consists of packets, which sizes are less than 97 bytes, and the rest 50 % belongs to the packets, which sizes are from 1434 to 1514 bytes (Fig. 5). Further investigations have shown that the main programs used in the Internet are p2p and www. Also it was stated that the traffic in all of these programs consists of small size packets. From the experiments it must be said, that the essential part of data traffic is covered by virus or other intrusive data, and this becomes a more and more warring question of network security.

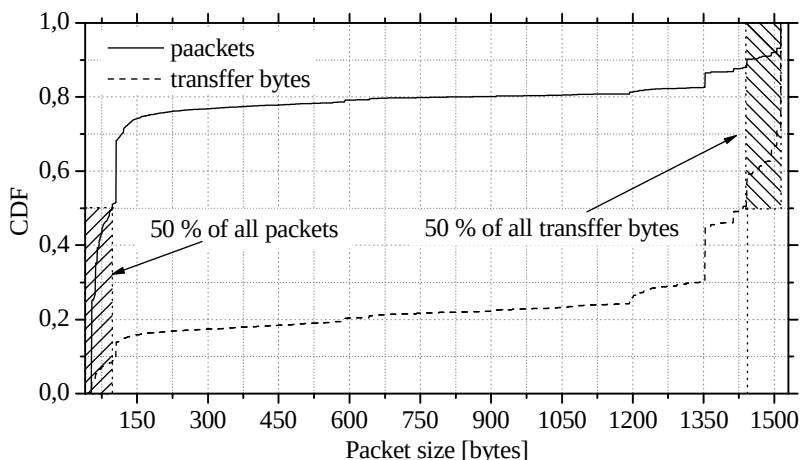


Fig. 5. CDF of packet size
5 pav. Paketų dydžių pasiskirstymas

On the ground of the above-described investigations the model of data traffic was described. The best way to annotate the data traffic is a self-similar model, and a model of Poisson is most inappropriate. It is clear that features of self-similarity are manifested even in short time intervals (less than 15 min.) though then Hurst value is not typical. It becomes more alike to the parameters described in scientific literature only in long time intervals.

Voice traffic examination

Well and widely known algorithms of coding and compression are described as G.729, G.723.1 codes of ITU recommendations or as other codes valid by digital means processing and used for reduction of data volume, i.e.

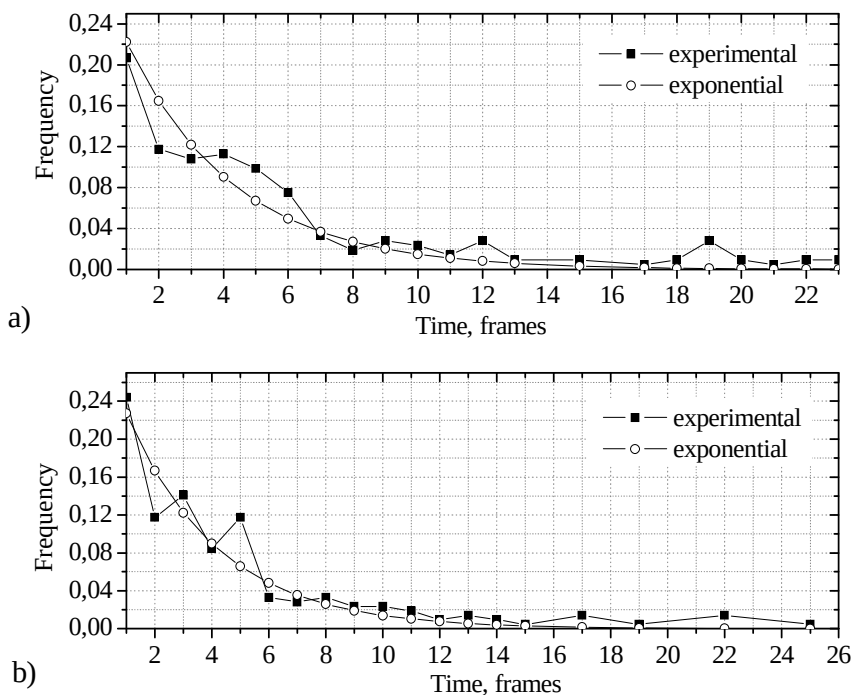


Fig. 6. a – distribution of voice intervals performed by two authors, b – distribution of silence intervals performed by the same authors

6 pav. a – dviejų autorių kalbos intervalų pasiskirstymas, b – ir tų pačių autorių tylos intervalų pasiskirstymas

detectors of voice activity, which are able to extract periods of talkspurt when a person really speaks and periods of silence when a speaker falls silent.

Experiments for clearing out the voice model using 3GPP AMR as detector of voice activity (frame size 30 ms) were carried out. They helped to determine the distribution law of speech-silent intervals. It was stated that this law does not diverge a lot from the exponential law (Fig. 6). And that voice intervals of speech-silent are correlated and that is the reason why the dispersion of mutual speech-silent period is less than the dispersion of analogous independent intervals. According to verified voice source model, special software for generation of synthetical voice data traffic was created.

Efficiency examination of voice transmission through WLAN

For the attainment of voice traffic transmission through WLAN possibilities efficiency computation of voice transmission through IEEE 802.11 a/b/g was executed.

The search of this chapter concentrated on the dependency of channel load on voice compression and physical channel protocol. The dependence of channel load from voice coding algorithm is shown in Fig. 7 but it seems that the channel load is much more dependable from packet formation time than from voice coding algorithm. The figure explains that when the time of packet formation is short, like 10 ms (G.711-1), the channel load increases 2,75 times comparing to the long formation time (G.711-3).

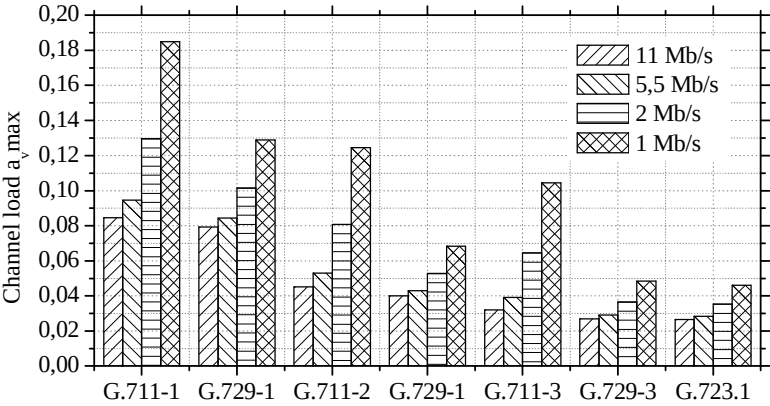


Fig. 7. IEEE 802.11b channel load with RTS/CTS without CRTP
7 pav. Kanalo apkrova IEEE 802.11b tinklė su kanalo RTS/CTS be CRTP

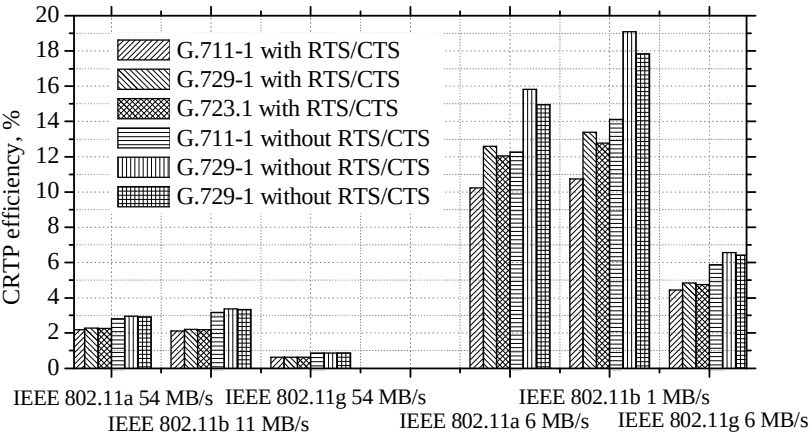


Fig. 8. The efficiency of CRTP protocol
8 pav. CRTP protokolo efektyvumas

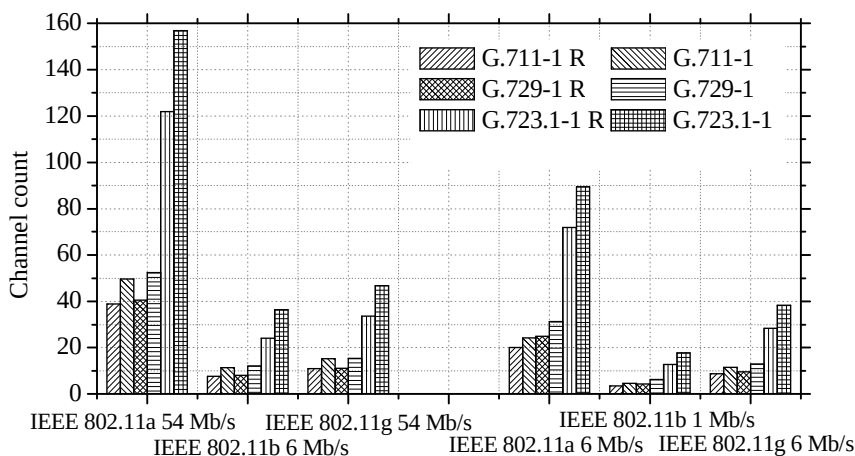


Fig. 9. IEEE 802.11 voice channel count

9 pav. IEEE 802.11 suminis balso kanalų skaičius

For the reduction of the packets' headers overhead the CRTP protocol is used. This protocol is applicable only in point to point connections. The efficiency of packet compression CRTP protocol is shown in Fig. 8. According to it, while transmitting voice through IEEE 802.11 network the channel load had decreased from 4 to 20%. The relative efficiency of the protocol increases when the transmission traffic decreases.

Total of voice channel quantity, which is subject to channel traffic and voice coding algorithm, is shown in Fig. 9. All transmissions that were made handling the RTS/CTS channel reservation are marked with R. The presented data shows openly that, while transmitting voice through IEEE 802.11b protocol network, the complex voice compression algorithms (G.723.1) cannot impact greatly on channel throughput's disengagement. In this case the channel load, created by voice transmission, comparing to G.711 protocol decreases only slightly.

5. WLAN adaptation for CPN

The third chapter illustrates that fact that the main WLAN efficiency is bigger while transmitting large size packets and it decrease drastically while transmitting small size packets. The fourth chapter states that mutual data traffic, created by modern information technologies, consists mainly from small size packets and their direct transmission leads to a very irrational usage of channel throughputs. This chapter explains other possibilities and yet

unused methods to decrease the volume of transmitted packets. In this work a special packet complex multiplexer KMUX is proposed, which group's small voice and data packets into amount frame for mutual transmission. After deep and comprehensive analysis on available multiplexing protocols and algorithms it was clear that non of them is suitable for usage in CPAN networks because of their particularity. These are the objectives for creation of KMUX algorithm:

- 1. to group data and voice packets of various sources and types;
- 2. to have an opportunity to change time of buffer formation;
- 3. to be transparent for TCP, UDP and higher protocols;
- 4. to be transparent for network devices that function in network level;
- 5. to have a system of service quality.

The objectives Nr. 3 and 4 point out that IP used as network protocol is the most suitable for creation of KMUX. KMUX data packet structure is shown in Fig. 10.

MAC header (14-40 bytes)	IP header (20 bytes)	KMUX header (0-127 bytes)	1-st data packet	l-ed data packet	...	n-ed data packet
MAC header	Multiplexing header		Data packets			

Fig. 10. Data packet structure of KMUX protocol

10 pav. KMUX paketo struktūra

For QoS support there was created a new type of device for transmission of the content of buffer. This new type allows creating separate buffers for separate kind of data traffic with separate timers for transmission. The station has a number of different buffers for various priorities because this helps to decrease the packet delay, which is created by multiplexing. Data, which is sensitive to delays, for example, voice, is placed in the higher priority buffer and data, which is not sensitive to delays, is placed in the lower priority buffer. The duration of the higher priority buffer's timer is smaller, and for this reason a packet stays in buffer a shorter period of time. This means that its delay is smaller. After timer goes off, in case the multiplexing packet has free space, some packets from the higher priority buffers are attached to the first one. If there are no such, packets from the lower priority buffers are attached. The same proceeds until the size of mutual packet expands to maximum. Following this routine the content of buffers may be transmitted even before the fixed time of timer. This helps to prevent packet delay and secure the efficiency of channel exploitation by maximizing the size of transmitted packets. This kind of buffers contents transmission may be called adaptive.

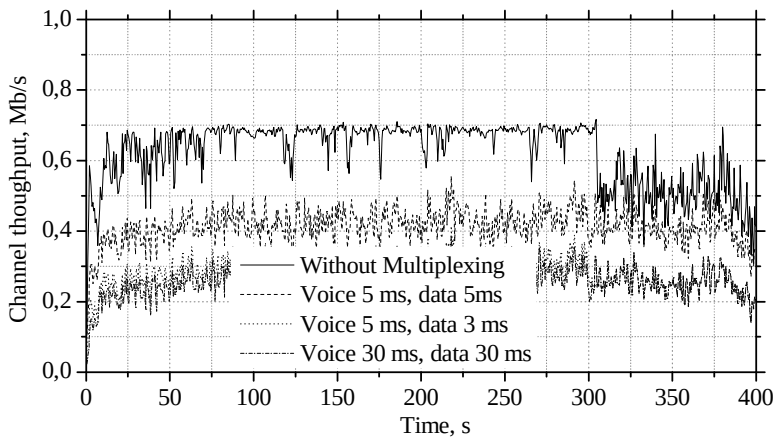


Fig. 11. The results of simulation of data transmission
11 pav. Duomenų perdavimo modeliavimo rezultatai

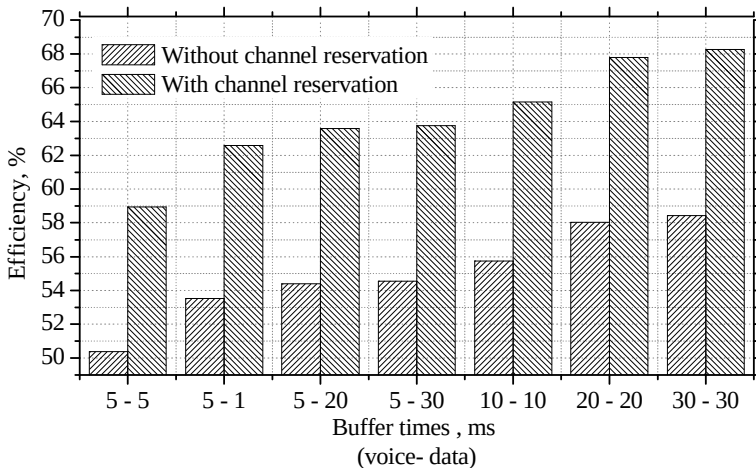


Fig. 12. The dependence of multiplexing efficiency on buffer time
12 pav. Multipleksavimo efektyvumo priklausomybė nuo buferio laiko

The software was created for the examination of new multiplexing algorithm. It operates in Unix OS in language C and is compounded of more than 4000 lines. The material for examination was generated by 30 voice sources coded with G.723.1 6,3 kb/s with/without VAD and 2 Mb/s Internet data traffic. The model had two types of buffers that have separate timer set: one for data and one for voice. The results of simulation are shown in Fig. 11-13. To be more precisely, the Fig. 11 shows the load of the channel, when

voice and data traffics are transmitted with or without multiplexing. It is clear to see, that even if time for filling in the voice and data into multiplexing buffers is as small as 5ms after switching on the multiplexing function, the traffic is definitely reduced by two times. Fig. 12 is helpful to explain how multiplexing efficiency, which is defined as a part of saved transmission time expressed in percentage, depends on buffer timer's value. As the buffer timer's value increases, the efficiency appears to be higher. It is worth to mention that the impact of voice buffer timer's value on multiplexing efficiency is stronger than the data one (see Fig. 12, 4-5 row) because the voice traffic consists only of small packets whereas in data traffic there are packets of various sizes.

Finally, the distribution of packets size modulation results is shown in Fig. 13. It points that the increase of buffer timer's value stimulates the larger number of large packets transmitted through the network. Even if the buffer timer's value is only 5 ms, the amount of half of the packets is more than 1000 bytes, whereas when there is no multiplexing proceeded the amount of half of the packets becomes less than 100 bytes. During the simulation the users were linked with wireless station through IEEE 802.3 interface, which allows transferring a MTU (Maximum Transfer Unit) equal 1500 bytes. That is why after switching off the multiplexing function, as it is shown in the Fig. 13, the maximum packet size accordingly is up to 1500 bytes. Nevertheless the IEEE 802.11 standard allows MTU to exceed even till 2313 bytes. And this feature helps to raise higher the exploitation of channel by adding smaller packets to the large ones sent by the users of stations that are connected by IEEE 802.11 standard communication channel after the multiplexing is switched on. The

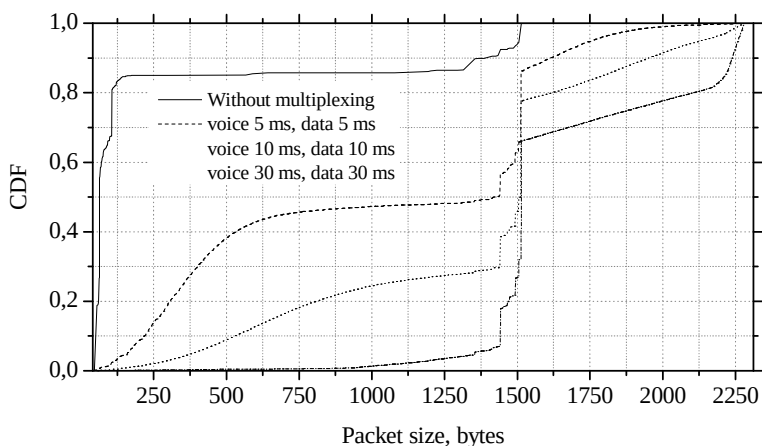


Fig. 13. CDF of packet size of multiplexing data stream

13 pav. Multipleksuoto srauto paketų dydžių dažnio tikimybių funkcija

distribution of packet delay due to multiplexing is shown in 14 Fig. It is clear to see that 10 % of all packets are transmitted with no additional delay and the delay of the rest is distributed evenly.

In conclusion it must be said that in case of using the above-mentioned multiplexing algorithm it is possible apparently to increase both the efficiency of channel utilization and the capacity of CPN.

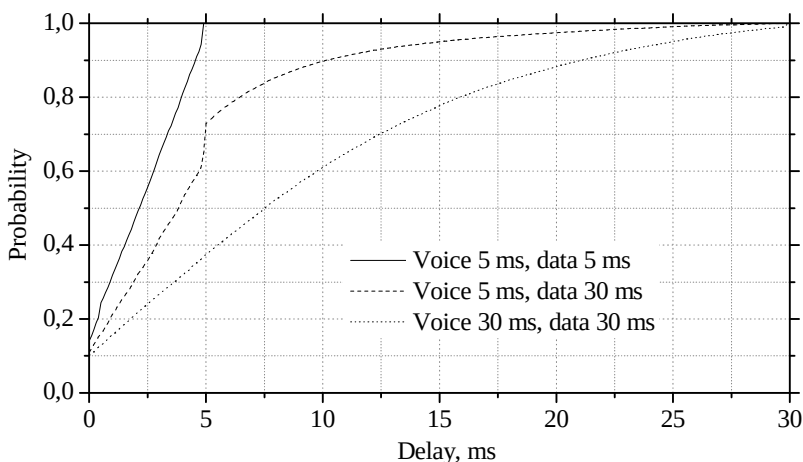


Fig. 14. Packet delay distribution depending on buffer timer's value
14 pav. Paketų vėlinimo pasiskirstymas priklausomai nuo buferių laiko

6. THE SUMMARY OF THE RESULTS

1. The means of radio communication in customers' access networks are the real and substantive alternative to the means of fixed communications sphere where monopolies of Telco's still predominate.
2. The experiments of IEEE 802.11a/b standard technologies were carried out both in the laboratory and outdoors. The results show clearly that the levels of signal and noise while working in stationary lines vary only slightly. For this reason it is recommended to implement the above mentioned technology in customers' access networks.
3. Typical devices constructed on the basis of IEEE 802.11b standard may be successfully implemented in sporadic customers' access networks to connect mutual telephone networks with the networks of internet services providers, in the case when the distance between stations is from several hundreds meters up to 20 km.

4. When the sources of voice are a few and the other load is not high (the average load is not higher than 50% of monochannel conduction), the efficiency of the channel is not important. According to these conditions the standard IEEE 802.11b installation equipment should be used.
5. The results of this research indicate apparently that complex algorithms for voice compression, like G.723.1, despite various network management functions, give small effect. Significantly, comparing to G.711 protocol, voice codecs are unable to reduce the channel load created by voice transmission.
6. Nowadays voice is coded by using G.711 protocol in PSTN. It is unnecessary to reconvert voice code in the gateways between PSTN and CPN, if G.711 is used in CPN. In other cases, voice codes should be changed for CPN for connecting with PSTN networks. This change reduces voice quality. According to factors mentioned above, it is purposive to use G.711 codec in CPN and send voice packets blocked together by 240 and more bytes.
7. The investigations on the duration of coded voice signal's speech-silence intervals and their interconnections show that the durations of contiguous intervals are correlated. Typical correlation is negative, and because of that dispersion of mutual speech-silent period is less than the dispersion of analogous independent intervals.
8. In order to increase the efficiency of packet transmission through extremely heaped channels a new data and voice multiplexing algorithm was proposed.
9. Also new software for packet multiplexing is created. The models examination helped to ascertain the impact of the parameters of multiplexing algorithms for its efficiency.
10. The suggested method for packet multiplexing designed for customers' access networks enables to transmit both data and voice packets at the same time and provide customers with maximum telecommunication services for the lowest price.

PUBLICATIONS

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REZIUMĖ

Temos aktualumas

Šiuo metu vykstanti sparti telekomunikacijų rinkos liberalizacija skatina atsirasti vis daugiau naujų paslaugų tiekėjų. Tačiau telekomai, turėję telekomunikacijų rinkos monopolį, vis dar dominuoja vietinių prieigų srityje, sulaukdami nedidelės konkurencijos iš naujų rinkos dalyvių ir tokiu būdu išlaikydami aukštus linijų nuomos tarifus. Naujai į rinką atėję operatoriai, kurie nėra linkę nuomotis ryšio kanalų iš egzistuojančių telekomų, privalo tiestis naujas ryšio linijas. Tačiau tai tinka tik tuo atveju, kai vietovės yra tankiai apgyvendintos, t.y. ten, kur vartotojų skaičius yra didelis, tuo tarpu mažai apgyvendintose vietovėse tai daryti per brangu. Tokiose vietovėse labiau tinka naudoti bevielės kreipties tinklus. Tam tikslui paslaugų tiekėjams buvo sukurta įranga, specialiai skirta fiksuotai bevelei kreipčiai, ir paskirti atitinkami dažnių ruožai. Vis dėlto tokia technologija nėra plačiai paplitusi dėl aukštų diegimo kainų politikos, todėl kaip alternatyva fiksuotai bevelei kreipčiai vis dažniau yra siūloma naudoti bevelius vietinius tinklus, pavyzdžiui, IEEE 802.11 ar ETSI HiperLAN standartų šeimą. Tokių tinklų pagrindu įmanoma kurti alternatyvius telekomunikacinius tinklus.

Iki šiol nėra atlikta detali tokių technologijų, skirtų didelės spartos ryšiiui retai apgyvendintose urbanizuotose vietovėse diegti, analizė, nors darbų skaičius šia tema didėja. Todėl šiuo darbu yra bandoma papildyti tokių tyrimų sąrašą bei paskatinti alternatyvius egzistuojančių ryšių technologijų panaudojimo tyrimus Lietuvoje. Ateityje šio darbo pagrindu būtų galima kurti regioninius plėtros planus bei skatinti informacinių sistemų plėtrą Lietuvai integravusis į Europos Sąjungą.

Darbo tikslai ir uždaviniai

Šio darbo tikslas – išnagrinėti šiuolaikines radijo ryšio technologijas ir parengti metodiką bei priemones jų įdiegimui vartotojų prieigų tinkluose.

Darbo tikslui įgyvendinti formuluojami šie uždaviniai:

1. išnagrinėti standartizuotus bevielio ryšio įrenginius ir sukurti metodiką jų galimybės netipinėse vartotojų prieigų tinklų sąlygose vertinti;
2. eksperimentiškai ištirti bevielio radijo ryšio priemones, veikiančias nelicencijuojamame dažnyje, ir nustatyti esminius parametrus;
3. išnagrinėti balso kodavimo būdus ir patikslinti balso sukuriamų duomenų srautų modelius;
4. ištirti informacinių technologijų vartotojų sukuriamų duomenų srautus ir parinkti jų modelius;
5. parengti metodiką ir priemones racionaliame bevielio ryšio technologijų vartojimui informacinių technologijų vartotojų prieigų tinkluose.

Mokslinis naujumas ir praktinis darbo rezultatų taikymas

Pasaulyje atlikta daug darbų vartotojų prieigų optimizavimo, naujų technologijų ir protokolų kūrimo srityse, pradedant nuo fundamentalių radijo ryšio moduliacijų iki ekonominių vartotojų prieigų tyrimo aspektų. Standartizuotų LAN ir WLAN tinklų įranga tiriama ir adaptuojama tipinėms duomenų perdavimo sąlygoms, kai tinklas yra arba su aiškia infrastruktūra, arba kai jos visiškai nėra (ad hoc versija). Šio darbo tyrimo objektas – tai netipinis vietinis tinklas, sukurtas standartizuotų LAN ir WLAN tinklų įrenginių pagrindu, toliau vadinamas vartotojų prieigų tinklu (VPT). VPT būtini prieigų prie bendrųjų tinklų resursų punktai (infrastruktūros požymiai), o vartotojų įranga veikia ir kaip terminalai, ir kaip retransliatoriai (ad hoc mazgų funkcijos). Tokia mišri tinklo architektūra yra nauja, šia tema atlikta mažai tyrimų.

Esminiai šio darbo naujumo elementai:

1. Lietuvos sąlygomis eksperimentiškai ištirti IEEE 802.11b standartų įrenginiai;
2. pasiūlyti vartotojų prieigų tinklai, jų vertinimo kriterijai;
3. nustatytos balso kalbos/tylos intervalų tarpusavio koreliacinės savybės;
4. riboto laidumo radijo ryšio kanalo panaudojimo efektyvumui didinti pasiūlytas balso ir duomenų bendro grupavimo protokolas, atlikti jo tyrimai;
5. grupavimo protokole pasiūlyta adaptyvi išsiuntimo schema, atlikti jos tyrimai.

Disertacijoje gauti rezultatai gali būti tiesiogiai taikomi kuriant ir diegiant vartotojų ar kitokius tinklus, kuriuose kaip informacijos transportavimo priemonė naudojami IEEE 802.11 standarto įrenginiai. Balso ir duomenų paketų grupavimo – multipleksavimo algoritmas gali būti panaudotas ir kitų tinklų „butelio kaklelio“ susidarymo vietose.

Darbo aprobavimas

Disertacijos tema paskelbta 9 mokslo darbų, iš kurių 4 Lietuvoje pripažintuose žurnaluose, 2 užsienio konferencijų darbų rinkiniuose ir 3 atspausdinti kitų konferencijų darbų medžiagose. Disertacijos tema perskaityta 13 pranešimų, iš kurių 2 užsienyje.

Gynimui pateikiama:

1. Radijo technologijų vertimo metodika.
2. Eksperimentiniai IEEE 802.11a/b protokolo tyrimai.
3. Balso kalbos/tylos intervalų koreguotą modelis.
4. Paketų grupavimo algoritmas.

Disertacijos struktūra ir apimtis

Disertaciją sudaro 6 skyriai ir vienas priedas. Įvadiname skyriuje aiškinamas disertacijos temos aktualumas, dėstomi darbo tikslai ir uždaviniai, metodiniai darbo principai, mokslinis naujumas ir rezultatų panaudojimas, darbo aprobacijos ir publikacijos, formuluojami ginami teiginiai, nurodoma darbo struktūra ir apimtis. Antrame skyriuje pateikiama radijo prieigų technologijų apžvalga. Prieinama išvada, kad radijo ryšio priemonės vartotojų prieigų tinkluose – tai alternatyva laidinio ryšio priemonėmis. Tačiau šiuo metu realistiškiausia technologija IEEE 802.11a, b bei g neskirta į sujungimus orientuotoms paslaugos teikti, todėl ją taikant vartotojų prieigų tinkluose reikia ieškoti būdų, kaip išlaikyti priimtina paslaugos kokybę, ir racionaliai išnaudoti radijo kanalo galimybes. Trečiame skyriuje formuluojama vartotojų prieigų tinklų sąvoka bei požymiai. Aprašomi bevielio lokalaus tinklo parametrai bei charakteristikos (1 pav.), pateikiami eksperimentinių duomenų tiriant IEEE 802.11b standarto įrangą Lietuvoje rezultatai (2 – 4 pav.). Nustatyta, kad bevelius tinklus, veikiančius IEEE 802.11 pagrindu, galima taikyti kuriant vartotojų tinklus. Ketvirtame skyriuje nagrinėjami duomenų ir balso šaltiniai bei jų modeliai. Pateikiami eksperimentiniai balso ir duomenų srautų tyrimo rezultatai (5 – 9 pav.) Taip pat šiame skyriuje yra pateikiami patikslintų balso ir duomenų šaltinių modeliavimo rezultatai. Penktame skyriuje aprašomi duomenų multipleksavimo metodai. Pateikiama sukurto kompleksinio multipleksavimo algoritmo aprašymas (10 pav.), modeliavimui sukurtos programinės įrangos struktūra, modeliavimo pradiniai duomenys bei multipleksavimo algoritmo modeliavimo rezultatai (11 – 14 pav.). Modeliavimas parodė, kad sukurtas metodas leidžia išlaisvinti iki 70 % kanalo resurso. Visi darbo metu gauti rezultatai apibendrinti šeštame skyriuje. Disertacijos pabaigoje pateikiamas literatūros sąrašas, kuriame nurodomi 182 kitų autorių bibliografiniai šaltiniai ir 9 disertacijos autoriaus publikacijų bibliografijos šaltiniai.

Disertacijoje yra 147 teksto puslapiai, 16 lentelių, 107 paveikslai, 191 bibliografijos šaltinio sąrašas. Disertacijos priedas yra kompaktinė plokštelė su programų išeities tekstais.

Atlikto darbo svarbiausi rezultatai ir jų apibendrinimas

1. Radijo ryšio priemonės vartotojų prieigų tinkluose – tai reali alternatyva laidinio ryšio priemonėms.
2. Atlikti IEEE 802.11a/b standarto įrangos eksperimentiniai tyrimai laboratorijos ir lauko sąlygomis leidžia teigti, kad signalo ir triukšmo lygiai stacionariose linijose kinta nežymiai, todėl minėtą įrangą galima rekomenduoti vartotojų prieigų tinklams.

3. Tipiniai IEEE 802.11b standarto pagrindu sukurti įrenginiai gali būti sėkmingai naudojami pavienių vartotojų tinklų prieigose ryšiui su bendraisiais telefono tinklais ir interneto paslaugų teikėjų tinklais palaikyti, kai atstumas yra nuo keleto šimtų metrų iki maždaug 20 km.
4. Kai balso šaltinių nedaug ir kita apkrova nėra aukšta (bendra apkrova neviršija 50% monokanalo laidumo), taikytina standartinė IEEE 802.11 a/b/g įranga.
5. Pateikti rezultatai akivaizdžiai rodo, kad perduodant balsą IEEE 802.11b protokolo tinklu sudėtingi kalbos kompresijos algoritmai (G.723) duoda palyginus menką efektą, balso sukuriamą kanalo apkrova lyginant su G.711 protokolu mažėja nežymiai.
6. Šiuo metu viešuosiuose telefono tinkluose balsas koduojamas G. 711 protokolu. Todėl nagrinėjant balso perdavimą VPT, reikia atsižvelgti į tai, kad sąsajose su viešaisiais tinklais koduoto balso nereikia papildomai perkoduoti tik tuo atveju, jei jis koduotas G.711 protokolu. Bet koks papildomas balso perkodavimas kokybės nepagerina, todėl mažai apkrautose VPT linijose tikslinga taikyti G.711 kalbos kodavimo protokolą papildomai sublokuojant kalbos paketus po 240 ir daugiau baitų.
7. Eksperimentiškai tyrinėjant koduoto balso signalo kalbos ir tylos intervalų trukmes bei jų tarpusavio ryšius nustatyta, kad gretimų intervalų trukmės yra koreliuotos. Tipinis koreliacijos koeficientas yra neigiamas, todėl bendro kalbos ir tylos periodo dispersija mažesnė lyginant su nepriklausomų analogiškų periodų dispersija.
8. Sukurtas naujas duomenų ir balso paketų grupavimo algoritmas, pagerinantis ekstremaliai apkrautų ryšio kanalų naudojimo efektyvumą.
9. Sukurta programinė įranga paketų grupavimo priemonėms modeliuoti. Modeliavimo būdu išnagrinėta grupavimo algoritmo parametų įtaką jo efektyvumui.
10. Atliktų tyrimų pagrindu pasiūlytas vartotojų radijo prieigų kūrimo būdas naudojant standartines bevielio ryšio priemones mažai apkrautoms linijoms ir papildant jas programinėmis paketų grupavimo priemonėmis aukšto intensyvumo kryptyse.

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RADIO TECHNOLOGIES IN CUSTOMER'S ACCESS NETWORKS

Summary of doctor dissertation

Technological Sciences, Electrical and Electronic Engineering (01T)

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