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Analysis of the Connection Level Technological Expenditures of Common WLAN Models

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Introduction

IEEE 802.11 based WLAN's technologies are gaining popularity for multimedia applications in campus networks, such as university places, airports, and other Hot-Spot districts, where volatile expanded concentration of customers may be observed. Such customers are users of multimedia services which use conditionally low recourses of networking and usually are connected to wired networks by DSL.

The IEEE 802.11 WLAN equipment is not expensive; therefore it was developed to be used for mobile computing devices, such as laptops, cell phones or PDAs in LANs, where packet switching is used for data interchange. Such network basically consists of two components: AP and nodes (STA's). AP is interface of WLAN to backbone network, while STA is the wireless part of WLAN named by BSS in standard [1] which are used to implement networks with small quantity of customers and fixed customer premise access links.

To support customer access WLAN architectures in the IEEE 802.11 MAC two services are implemented DCF and PCF. In DCF, STA's contend for access asynchronously. By contrast, in PCF, STA's are polled from a PS. PCF support time-bounded services as well as transmission of asynchronous data, voice, or mixed.

There are many research works where DCF and PCF are being analyzed in different aspects. For WLAN protocols modernization or perfection many task solutions are proposed. References [2], [3], [4] studied the use of DCF to support VoIP. Voice Capacity in IEEE 802.11a/b/g WLAN's is investigated very well. The delays and their variation margins are determined. It's showed, that capacity to accommodate voice traffic in DCF is very limited and is not efficient in supporting the delay-sensitive voice traffic. The contention-based nature and exponential backoff mechanism can not guarantee that a voice packet is successfully delivered within the delay bound.

Controlled access is more suitable for voice traffic delivery, because of its less overhead and guaranteed delay performance. The capacity of a system that uses the PCF for CBR and VBR voice traffic was analyzed in [5] and [6]. The VBR voice traffic was simulated using ON-OFF voice source model. Detailed overview of Voice capacity, admission control and QoS is proposed in task [7].

In this task the analysis presented in [8] is preceded. The main consideration is focused on the features of signals transmission of few conversations in the same time through IEEE 802.11 based customers access WLAN's. Hereby, the analysis of technological redundancy of connection level is introduced. Offered method let to analyze technological expenditures for RT traffic in IEEE 802.11 infrastructure networks by applying ITU P.59 [9].

The aim of presented analysis is to realistically calculate WLAN expenditures for support of telephony services and remnant capacity of overall channel for real data transmissions and to find particular limits and conditions when IEEE 802.11 technologies in PCF mode are fully expedient. Analysis is made considering that the PCF is implemented and the beacon rate is equal to voice coding rate in the network.

Presented work will allow seeing the features of such technologies in more attentive way. This enables to generate other, more superior solutions which may provide services of DSL quality level in the WLAN's. These possibilities will be detailed analysed in future works.

Abbreviations

Network component marking: AP/PC – Access Point/Point Coordinator, STA – End user station.

Protocol components: WLAN – Wireless LAN; DCF - Distributed Coordination Function; PCF - Point Coordination Function; CFP – Contention-Free Period ; CP – Contention Period; CSMA/CA - Carrier Sense Multiple Access with Collision Avoidance; SSID - Service Set Identity; ACK – Acknowledgment; SIFS – Short Inter Frame Space; PIFS – PCF Inter Frame Space; VAD - Voice Activity Detection; RT – Real Time Traffic; NAV – Network Allocation Vector; MPDU– MAC Protocol Data Unit; PPDU – PLCP Protocol Data Unit; TIM - traffic indication message; DTIM – delivery TIM; MAC – Medium Access Control; PHY – Physical Layer; Null –

Null Frame; SF – Superframe. User Data – encapsulated data of upper OSI layer in the Frame Body of MPDU.

IEEE 802.11 PCF

The DCF mode is the fundamental access method of the 802.11 MAC sublayer and is based on CSMA/CA. To support applications that require near RT traffic, the IEEE 802.11 standard [1] includes an optional PCF which allows an 802.11 network to provide an enforced "fair" access to the medium. PCF allows to provide contention-free frame transfer and to thus support time-bounded services as well as transmission of asynchronous data, voice, or mixed.

By implementing PCF the time on the medium is divided into two parts: CFP controlled by PCF and CP controlled by DCF [1] (Fig. 1). The PC performs control of the medium at the beginning of the CFP after sensing the medium to be idle for a PIFS period. When the medium is determined to be idle for one PIFS, the PC shall transmit a Beacon frame. When beacon frame is send other STA detects the beacon frame and sets the NAV for the whole CFP. This ensures that STA will not attempt to access the channel. The priority of PCF over DCF is guaranteed with PIFS being shorter than DIFS: $\tau_{\mathrm{SIFS}} < \tau_{\mathrm{PIFS}} < \tau_{\mathrm{DIFS}}$.

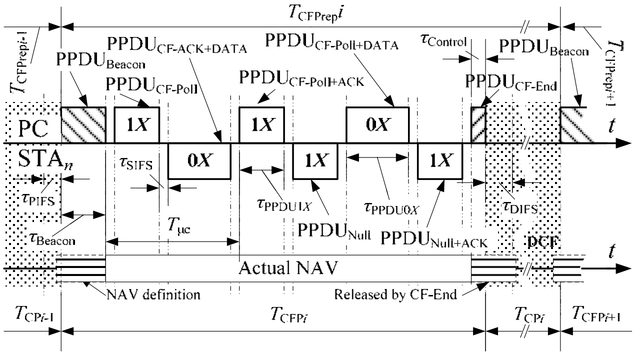

Fig. 1. IEEE 802.11 operation in PCF mode

Alternating periods of contention-free service and contention-based service repeat at regular intervals, which are called the CF repetition interval (T_{CFPrep}) (Fig. 1). The relative duration of the T_{CFPrep} may be configured separately in equipment. It's because the PCF is designed for support services that require near real-time service.

The Consignments and models of CFP: Static model

After detailed analysis of standard [1] we exclude for our purposes the base defined rules of PCF operation (employed during the CFP period):

1. After the initial Beacon frame, the PC shall wait for one SIFS period, and then can transmit one MPDU.
2. The PC sends polling messages to the CF-Pollable n-th STA only once during each SF.
3. The PC transmits Data Frame with CF-Poll index with each transmitted MPDU.
4. If PC has buffered data to n-th STA, PC transmit Data Frame with CF-Poll index label and data to n-th STA, otherwise the Data Frame with CF-Poll index has minimal length (no User Data). CF-Poll index is labelled in Type Control and Subtype subfields of Frame Control field in MPDU header of Data Frame.
5. Each transmitted MPDU must be ACK'ed by transmission CF-ACK command. The n-th CF-Pollable STA shall ACK after a SIFS period, the receipt of each Data⊕CF-Poll frame or Data⊕CF-ACK⊕CF-Poll frame using Data⊕CF-ACK or CF-ACK (no data) frames, the receipt of each CF-Poll (no data) using Data or Null, and the receipt of all other data and management frames using ACK Control frames. CF-ACK index is labelled in Type Control and Subtype subfields of Frame Control field in MPDU header of Data Frame.
6. The transmission of CF-Poll or CF-ACK command with DATA to n-th STA do not increase duration of MPDU. The Data Frames with CF-Poll or CF-ACK commands occupy the channel additionally when this commands transmitted like separate MPDU.

The content of MPDU transmitted by PC in i-th period of CF depends on fact: if the PC has data to transmit to n-th STA, and have the $(n\text{-}1)$-th STA transmitted data to PC in i-th period of CF (Fig.1). The PC may transmit four different formats of MPDU:

$$\mathrm{MPDU}_{0n} \Rightarrow \begin{cases} \mathrm{MPDU}_{\mathrm{CF\text{-}Poll}}, \\ \mathrm{MPDU}_{\mathrm{CF\text{-}ACK\oplus CF\text{-}Poll}}, \\ \mathrm{MPDU}_{\mathrm{DATA\oplus CF\text{-}Poll}}, \\ \mathrm{MPDU}_{\mathrm{DATA\oplus CF\text{-}Poll\oplus CF\text{-}ACK}}. \end{cases} \qquad (1)$$

If STA receives a CF-Poll Data Frame from the PC, it may send back Data Frame with a DATA or Null frame (if the STA has no buffered User Data to PC). The content of MPDU from n-th STA to PC depend on are the n-th STA has User Data to transmit to PC, and are the PC has send to n-th STA MPDU with CF-Poll command label and DATA. The n-th CF-Pollable STA must operate after a SIFS by sending follow Data Frames:

$$\mathrm{MPDU}_{n0} \Rightarrow \begin{cases} \mathrm{MPDU}_{\mathrm{Null}}, \\ \mathrm{MPDU}_{\mathrm{CF\text{-}ACK}}, \\ \mathrm{MPDU}_{\mathrm{DATA\oplus CF\text{-}ACK}}, \\ \mathrm{MPDU}_{\mathrm{DATA}}. \end{cases} \qquad (2)$$

According to IEEE 802.11 standard all MPDU frames are transmitted encapsulated to PPDU [1]. The structure of PPDU depends on revision of standard. In herein task the PPDU format of IEEE 802.11a standard is used. Detailed analysis of technological expenditures of this standard is provided in [8].

Times of PHY occupations

Transmissions between PC and STA are cyclic process. After the PIFS, Beacon (Management Frame), and SIFS the PC transmit PPDU_{0n}, and the n-th STA replay to it by transmission of PPDU_{n0}. Follow exchanges may by named by micro-cycles which composition with single STA is:

$$\mathrm{SIFS} \rightarrow \mathrm{PPDU}_{0n} \rightarrow \mathrm{SIFS} \rightarrow \mathrm{PPDU}_{n0}. \qquad (3)$$

The channel occupation of such micro-cycles depends on duration of PPDU_{0n} and PPDU_{n0}. The PPDU duration depends on size of encapsulated MPDU [8]. By reference to defined PCF operation rules all transmitted MPDU frames may be divided in two groups: Data Frames with

User Data ($0X$) and Data Frames without User Data ($1X$). Therefore the durations of PPDU_{0X} and PPDU_{1X} with encapsulated MPDUs (1), (2) may be defined:

$$\begin{aligned}\tau_{\mathrm{PPDU}1X} &= \tau_{\text{CF−Poll}} = \tau_{\text{CF-Poll}\oplus\text{CF-ACK}} = \\ &= \tau_{\text{CF- ACK}} = \tau_{\text{Null}};\end{aligned} \tag{4}$$

$$\begin{aligned}\tau_{\mathrm{PPDU}0X} &= \tau_{\text{DATA}\oplus\text{CF-ACK}} = \tau_{\text{DATA}\oplus\text{CF−Poll}} = \\ &= \tau_{\text{DATA}\oplus\text{CF−ACK}\oplus\text{CF−Poll}} = \tau_{\text{DATA}}.\end{aligned} \tag{5}$$

According to (8) and (9) of reference [8] the duration of PHY channel occupation by PPDU is:

$$\tau_{\mathrm{PPDU}} = 22 + 4 \cdot \frac{8 \cdot N_{\mathrm{MPDUover}}}{N_{\mathrm{DBPS}}(m)} + 4 \cdot \frac{8 \cdot N_{\mathrm{MPDU}}}{N_{\mathrm{DBPS}}(m)}. \tag{6}$$

Consequently, for PPDU_{0X} with $\mathrm{N}_{\mathrm{DATA}}$ bytes of User Data [8] the transmission duration over the IEEE 802.11a PHY channel depend on selected mode (m) and may be related by:

$$\tau_{\mathrm{PPDU}0X} = 22 + \frac{32\left(N_{\mathrm{MPDUover}} + N_{\mathrm{DATA}}\right)}{N_{\mathrm{DBPS}}(m)}, [\mu\mathrm{s}]. \tag{7}$$

According to standard [1], all technological frames have constant MPDU length H_{MAC}=28 bytes [8]. Therefore, for PPDU_{1X} the transmission duration over the IEEE 802.11a PHY may be related by:

$$\tau_{\mathrm{PPDU}1X} = 22 + \frac{896}{N_{\mathrm{DBPS}}(m)}, [\mu\mathrm{s}]. \tag{8}$$

The Control Type frames ($\mathrm{PPDU}_{\text{CF-End}}$, $\mathrm{PPDU}_{\text{CF-End}\oplus\text{CF-ACK}}$) have constant MPDU length H_{MAC}=20 bytes. Consequently, the channel occupation duration in CFP over the IEEE 802.11a PHY may be related by:

$$\tau_{\mathrm{Control}} = 22 + \frac{768}{N_{\mathrm{DBPS}}(m)}, \mu\mathrm{s}. \tag{9}$$

The lengths of Beacon frame is variable and depend on variable SSID and TIM fields [1]. In herein task SSID of 6 bytes length are used. The TIM field of Beacon frame depends on equipment configuration and in most cases the default value is 3. Hereby, the full length of TIM field is 6 bytes [1]. Therefore, the length of beacon frame is 64 bytes. Therefore, the time needed to transmit beacon is:

$$\tau_{\mathrm{Beacon}} = 22 + \frac{2048}{N_{\mathrm{DBPS}}(m)}, [\mu\mathrm{s}]. \tag{10}$$

Model of speech established traffic

The modern voice codec is generating voice packets at the constant rate only when a user is in the talking state and no voice packets are generated when a user is silent. Therefore voice source traffic consists of a succession of ON and OFF periods. Such single voice source model is applicable to analysis of systems with one direction transmissions. In wireless networks mutual (two directions) transmissions are operating, therefore conversational model when two talkers (A and B) are talking independently is more applicable. As follow conversational speech model is specified in the ITU P.59 recommendation [9]. The important feature of this recommendation that for model of the conversation between two users A and B as a four state Markov chain with states being: A talking B silent (A0), A silent B talking (0B), both talking (AB), both silent (00).

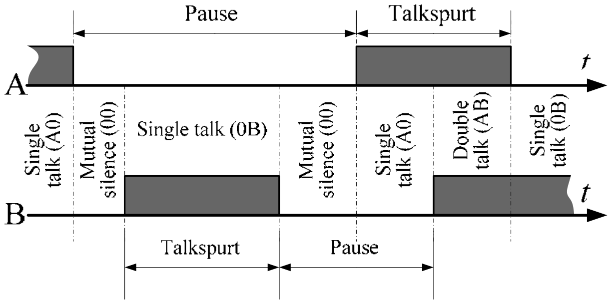

Fig. 2. Illustration of conversational speech model operation

Operation of such conversational speech model in the Fig. 2 is well illustrated. In the intermediate moments both talkers may be in silence or in mutual talk states when two talkers converse with each other. These states in specification [9] characterized by durations of the states intervals and by probabilities of them. The average durations of these intervals are empirical values proposed differently in various references. According to [9] the durations of states are mutually independent and identically distributed exponential uniform random variables with means 854 ms, 854 ms, 226 ms and 456 ms respectively. According these probabilities of the states is calculated and showed in Table 1.

Table 1. Probabilities of conversational voice model [9]

State	A0	0B	AB	00
$t_{[9]}$, μs	0,854	0,854	0,226	0,456
$p_{[9]}$	0,357	0,357	0,095	0,191

The obtained model of conversational speech in modelling of IEEE 802.11 PCF transmissions may be related by collation with micro-cycles. According to that in CFP cycle speaker A is in PC side, and speaker B is n-th STA and both of them may transmit for each other only one PPDU; it's possible to analyze the variable durations and connection-level expenditures in CFP. Variations of possible durations of micro-cycle's ($T_{\mu\mathrm{c}}$) between PC and n-th STA and probabilities of them ($p_{\mu\mathrm{c}}$) for i-th of CFP time are shown in Table 2.

Table 2. Possible micro-cycles for 1 STA

State	$p_{\mu\mathrm{c}}$	PPDU_{0n}	PPDU_{n0}	$T_{\mu\mathrm{c}}$
00	p_{00}	$\tau_{\mathrm{PPDU}1X}$	$\tau_{\mathrm{PPDU}1X}$	T_{00}
A0	p_{A0}	$\tau_{\mathrm{PPDU}1X}$	$\tau_{\mathrm{PPDU}0X}$	T_{A0}
0B	p_{0B}	$\tau_{\mathrm{PPDU}0X}$	$\tau_{\mathrm{PPDU}1X}$	T_{0B}
AB	p_{AB}	$\tau_{\mathrm{PPDU}0X}$	$\tau_{\mathrm{PPDU}0X}$	T_{AB}

In Table 2 T_{00}, T_{A0}, T_{0B}, and T_{AB} are durations of micro-cycles ($T_{\mu\mathrm{c}}$) in CFP for WLAN with one STA. According to performed analysis following durations may be related:

$$T_{00} = 2\left(\tau_{\mathrm{PPDU}1X} + \tau_{\mathrm{SIFS}}\right), \tag{11}$$

$$T_{\mathrm{A0}} = \tau_{\mathrm{PPDU}1X} + \tau_{\mathrm{PPDU}0X} + 2\tau_{\mathrm{SIFS}}, \tag{12}$$

$$T_{0\mathrm{B}} = \tau_{\mathrm{PPDU}0X} + \tau_{\mathrm{PPDU}1X} + 2\tau_{\mathrm{SIFS}}, \qquad (13)$$

$$T_{\mathrm{AB}} = 2\left(\tau_{\mathrm{PPDU}0X} + \tau_{\mathrm{SIFS}}\right). \qquad (14)$$

The channel occupation and duration of it doesn't depend on which node (PC or STA) is in talking state or silence state: $T_{\mathrm{A0}}= T_{\mathrm{0B}}$. Therefore Table 2 may be simplified by deletion of 0B state and probability p_{A0} of state A0 by changing to sum of probabilities of both states $p_{\mathrm{A+B}}=p_{\mathrm{A0}}+p_{\mathrm{0B}}$.

Table 3. Possible micro-cycles for 1 STA (simplified)

State	$p_{\mu c}$	**PPDU**$_{0n}$	**PPDU**$_{n0}$	$T_{\mu c}$
00	p_{00}	τ_{1X}	τ_{1X}	T_{00}
A0	$p_{\mathrm{A+B}}$	τ_{0X}	τ_{1X}	T_{A0}
AB	p_{AB}	τ_{0X}	τ_{0X}	T_{AB}

Possible micro-cycles of different durations and probabilities of them when in network operate 2 STA (2 pairs of communicated users) are shown in Table 4.

Table 4. Possible durations and probabilities of micro-cycles for 2 STA

A$_1$B$_1$	**A$_2$B$_2$**	$p_{\mu c}$	$T_{\mu c}$
00	00	p_{00}^{2}	$2T_{00}$
00	A$_2$0	$2p_{00}p_{\mathrm{A+B}}$	$T_{00}+T_{\mathrm{A+B}}$
00	A$_2$B$_2$	$2p_{00}p_{\mathrm{AB}}$	$T_{00}+T_{\mathrm{AB}}$
A$_1$0	A$_2$0	$p_{\mathrm{A+B}}^{2}$	$2T_{\mathrm{A0}}$
A$_1$0	A$_2$B$_2$	$2p_{\mathrm{A+B}}\,p_{\mathrm{AB}}$	$T_{\mathrm{A0}}+T_{\mathrm{AB}}$
A$_1$B$_1$	A$_2$B$_2$	p_{AB}^{2}	$2T_{\mathrm{AB}}$

Table 5. Possible durations and probabilities of micro-cycles for 3 STA

A$_1$B$_1$	**A$_2$B$_2$**	**A$_3$B$_3$**	$p_{\mu c}$	$T_{\mu c}$
00	00	00	p_{00}^{3}	$3T_{00}$
00	00	A$_3$0	$3p_{00}^{2}p_{\mathrm{A+B}}$	$2T_{00}+T_{\mathrm{A0}}$
00	00	A$_3$B$_3$	$3p_{00}^{2}p_{\mathrm{AB}}$	$2T_{00}+T_{\mathrm{AB}}$
00	A$_2$0	A$_3$0	$3p_{00}p_{\mathrm{A+B}}^{2}$	$T_{00}+2T_{\mathrm{A0}}$
00	A$_2$0	A$_3$B$_3$	$6p_{00}p_{\mathrm{A+B}}p_{\mathrm{AB}}$	$T_{00}+T_{\mathrm{A+B}}+T_{\mathrm{AB}}$
00	A$_2$B$_2$	A$_3$B$_3$	$3p_{00}p_{\mathrm{AB}}^{2}$	$T_{\mathrm{A+B}}+2T_{\mathrm{AB}}$
A$_1$0	A$_2$0	A$_3$0	$p_{\mathrm{A+B}}^{3}$	$3T_{\mathrm{A0}}$
A$_1$0	A$_2$0	A$_3$B$_3$	$3p_{\mathrm{A+B}}^{2}p_{\mathrm{AB}}$	$2T_{\mathrm{A+B}}+T_{\mathrm{AB}}$
A$_1$0	A$_2$B$_2$	A$_3$B$_3$	$3p_{00}p_{\mathrm{AB}}^{2}$	$T_{00}+2T_{\mathrm{AB}}$
A$_1$B$_1$	A$_2$B$_2$	A$_3$B$_3$	p_{AB}^{3}	$3T_{\mathrm{AB}}$

Table 6. Possible durations and probabilities of micro-cycles for 4 STA

A$_1$B$_1$	**A$_2$B$_2$**	**A$_3$B$_3$**	**A$_4$B$_4$**	$p_{\mu c}$	$T_{\mu c}$
00	00	00	00	p_{00}^{4}	$4T_{00}$
00	00	00	A$_4$0	$4\,p_{00}^{3}p_{\mathrm{A+B}}$	$3T_{00}+T_{\mathrm{A0}}$
00	00	00	A$_4$B$_4$	$4\,p_{00}^{3}p_{\mathrm{AB}}$	$3T_{00}+T_{\mathrm{AB}}$
00	00	A$_3$0	A$_4$0	$6\,p_{00}^{2}p_{\mathrm{A+B}}^{2}$	$2T_{00}+2T_{\mathrm{A0}}$
00	00	A$_3$B$_3$	A$_4$B$_4$	$6\,p_{00}^{2}p_{\mathrm{AB}}^{2}$	$2T_{00}+2T_{\mathrm{AB}}$
00	00	A$_3$0	A$_4$B$_4$	$12\,p_{00}^{2}p_{\mathrm{A+B}}p_{\mathrm{AB}}$	$2T_{00}+T_{\mathrm{A0}}+T_{\mathrm{AB}}$
00	A$_2$0	A$_3$0	A$_4$B$_4$	$12\,p_{00}p_{\mathrm{A+B}}^{2}p_{\mathrm{AB}}$	$T_{00}+2T_{\mathrm{A0}}+T_{\mathrm{AB}}$
00	A$_2$0	A$_3$B$_3$	A$_4$B$_4$	$12\,p_{00}p_{\mathrm{A+B}}p_{\mathrm{AB}}^{2}$	$T_{00}+T_{\mathrm{A0}}+2T_{\mathrm{AB}}$
A$_1$0	A$_2$0	A$_3$0	A$_4$0	$p_{\mathrm{A+B}}^{4}$	$4T_{\mathrm{A0}}$
A$_1$0	A$_2$0	A$_3$0	00	$4p_{\mathrm{A+B}}^{3}p_{00}$	$3T_{\mathrm{A0}}+T_{00}$
A$_1$0	A$_2$0	A$_3$0	A$_4$B$_4$	$4p_{\mathrm{A+B}}^{3}p_{00}$	$3T_{\mathrm{A0}}+T_{00}$
A$_1$0	A$_2$0	A$_3$B$_3$	A$_4$B$_4$	$6p_{\mathrm{A+B}}^{2}p_{\mathrm{AB}}^{2}$	$2T_{\mathrm{A0}}+2T_{\mathrm{AB}}$
A$_1$B$_1$	A$_2$B$_2$	A$_3$B$_3$	A$_4$B$_4$	p_{AB}^{4}	$4T_{\mathrm{AB}}$
A$_1$B$_1$	A$_2$B$_2$	A$_3$B$_3$	00	$4p_{\mathrm{AB}}^{3}p_{00}$	$3T_{\mathrm{AB}}+T_{00}$
A$_1$B$_1$	A$_2$B$_2$	A$_3$B$_3$	A$_4$0	$4p_{\mathrm{AB}}^{3}p_{\mathrm{A+B}}$	$3T_{\mathrm{AB}}+T_{\mathrm{A0}}$

By proceeding current analysis, the micro-cycles and their probabilities when in the WLAN operate 3 or 4 STA easily may be fulfilled. In Tables 5 and 6 the micro-cycles durations and probabilities of them are shown respectively.

The distributions of probabilities $p_{\mu c}$ of different durations of micro-cycles when 4 STA transmit voice packet coded by G.711 are shown in Fig. 3.

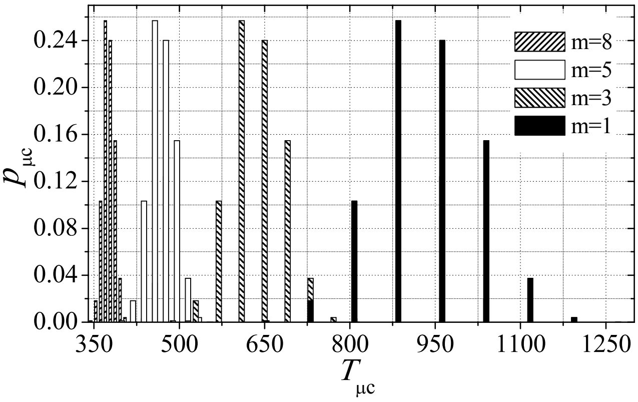

Fig. 3. Distribution of probabilities $p_{\mu c}$ of durations $T_{\mu c}$ in WLAN with 4 STA for G.711 [10]

Presented distributions of micro-cycles durations' probabilities to Gaussian normal distribution are close and depend on rate expressed by (m). The distribution in time axis is even, because in RT transmissions the equal frame length of time is used. For G.711 the payload length is 80 bytes [10]. The dispersion of $T_{\mu C}$ (Fig. 4) show that deflection of $T_{\mu C}$ is not intense, however depend on count of nodes in WLAN.

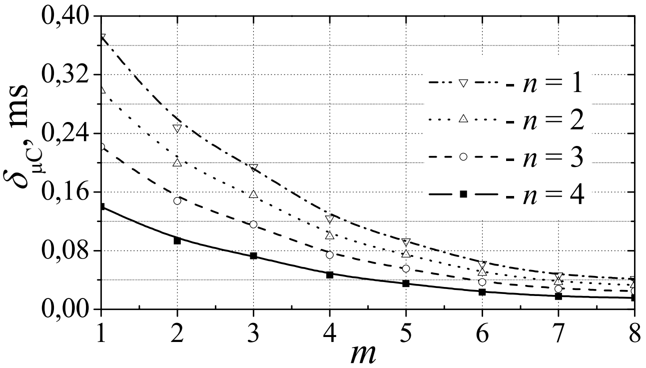

Fig. 4. Distribution of probabilities $p_{\mu c}$ of durations $T_{\mu c}$ in WLAN with 4 STA for G.711 [10]

In task [8] detailed analysis has shown that technological redundancy directly depend on one packet User Data payload length.

Technological redundancy in PCF is depending on duration of T_{CFPrep} period and T_{CFP} (Fig. 1). By considering with conversational speech model and according to [1] for CBR traffic, when with each frame of CFP micro-cycles the equal User Date payload (all in AB state) is transmitted, the maximal duration of CFP (T_{CFPmax}) may be expressed:

$$T_{\mathrm{CFPmax}} = nT_{\mu\mathrm{C}} + \tau_{\mathrm{Beacon}} + \tau_{\mathrm{Control}}, \qquad (15)$$

where n – is count of micro-cycles in the CFP. The n is equal to count of Pollable STA in WLAN.

The τ_{CFPmax} depend on count of STA in customer WLAN. The dependence of τ_{CFPmax} on IEEE 802.11a m value for G.711 with 20 ms packetization time according to [10] is shown in Fig. 5.

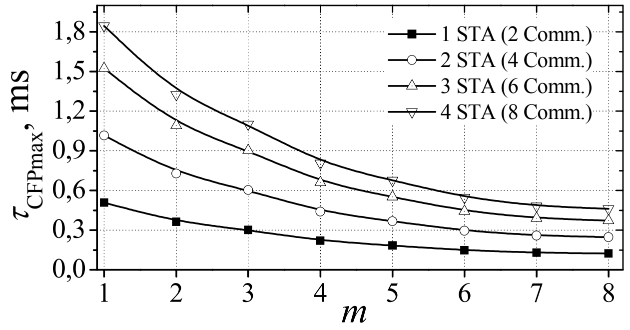

Fig. 5. Dependence of τ_{CFPmax} on m for ITU G.711 voice codec

The CFP duration for VBR voice traffic is variable value and depends on micro-cycle and variations of them. For elimination of such dependence the averaged duration of micro-cycles may be used:

$$\bar{\tau}_{\mu\mathrm{C}} = p_{00}\cdot\tau_{00} + p_{\mathrm{A+B}}\cdot 2\tau_{\mathrm{A0}} + p_{\mathrm{AB}}\cdot\tau_{\mathrm{AB}}. \tag{16}$$

Consequently the expression of CFP duration with $\bar{\tau}_{\mu\mathrm{C}}$ in generalized relation may be expressed:

$$\bar{\tau}_{\mathrm{CFP}} = \tau_{\mathrm{Beacon}} + \sum_{i=1}^{j} p_i\tau_i + \tau_{\mathrm{Control}}, \tag{17}$$

where i – is number of state combination in micro-cycles; j – is possible combinations of micro-cycle in CFP. The dependence of $\bar{\tau}_{\mathrm{CFP}}$ on value m for G.711 codec is shown in Fig. 6.

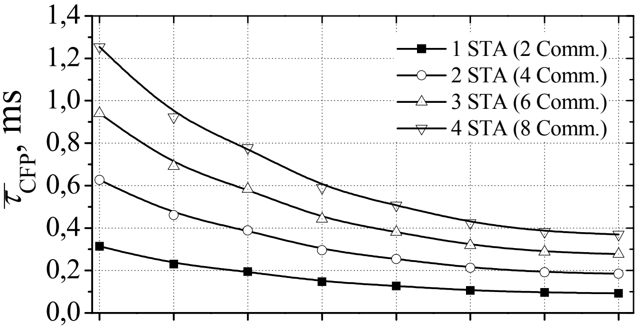

Fig. 6. Dependence of $\bar{\tau}_{\mathrm{CFP}}$ on m for ITU G.711 voice codec

Technological redundancy of CFP

Normalized value of technological redundancy index of the physical channel in [8] expressed for every packet by the relation:

$$\varepsilon_{\mathrm{PPDU}}(m) = \frac{T_{\mathrm{PPDU}}(m) - \tau_{\mathrm{DATA}}(m)}{\tau_{\mathrm{DATA}}(m)}. \tag{18}$$

Presented index formally for evaluation of single packet transmission in the PCF mode may be used. However such evaluation does not reflect all PCF features. For example, in period when both station in silence state (00) of the transmissions of voice packets the technological redundancy index on packet basis grows to infinity. For evaluation of voice communications others definitions of technological redundancy are needed.

By continuing consistent analysis, for evaluation of technological expenditures of CFP in connection-level $\bar{\tau}_{\mathrm{CFP}}$ must be used. Therefore the expression (18) may be rewritten:

$$\varepsilon_{\mathrm{CFP}}(m) = \frac{\bar{\tau}_{\mathrm{CFP}}(m) - \bar{\tau}_{\mathrm{CFP\text{-}DATA}}(m)}{\bar{\tau}_{\mathrm{CFP\text{-}DATA}}(m)}, \tag{19}$$

where $\bar{\tau}_{\mathrm{CFP-DATA}}$ – the average of time needed to transmit N_{DATA} [8] data in all micro-cycle of CFP. $\bar{\tau}_{\mathrm{CFP-DATA}}$ according (17) is:

$$\bar{\tau}_{\mathrm{CFP\text{-}DATA}} = \sum_{i=1}^{j} p_i\left(\tau_{\mathrm{DATA}}\right)_i, \tag{20}$$

where τ_{DATA} – expression analyzed in [8]. For RT traffic the dependence of the CFP connection-level technological redundancy on packet length is shown in Fig. 7.

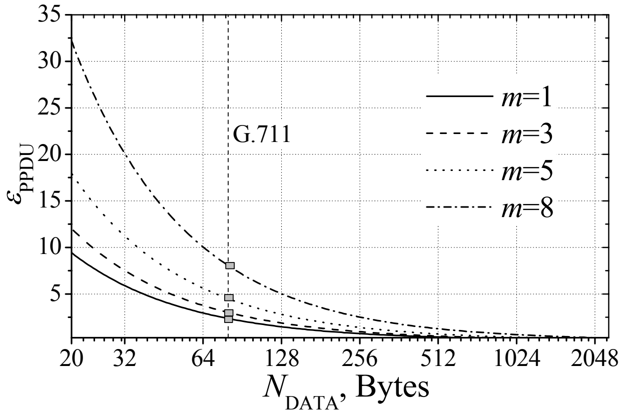

Fig. 7. Dependence of index $\varepsilon_{\mathrm{CFP}}$ on packet size

Technological redundancy of CFP depends on the length of transmitted packet. It notably increases when the small data packet is transmitted. Presented results according to (19) valid only for voice transmissions with VAD enabled, because for correct interpretation the rule that technological redundancy depend on codec must be accepted. Technological redundancy when G.711 codec is used is showed in graph. Therefore, the conclusion may be stated: the connection-level technological redundancy of CFP is heavy when codec's with high compression level is used. Connection-level redundancy may be explained for all codec's by the tendency to transmit frames with no User Data (N_{DATA}) (4) – 1X.

Conclusions

The investigation of technological expenditures in WLAN of IEEE 802.11 standard is presented in [8]. In herein work the analysis of connection level by fitting infrastructure networks for transmission of real time signals over WLAN's is extended – the investigation of technological redundancy is introduced by applying ITU P.59 recommendation.

The article reveals that in packet formation process for each data block transmitted over WLAN the headers of different protocols are appended. It should be noticed that by fitting allocation of transmission time's the additional time intervals are appended too. In the same CFP period between AP and particular STA only one frame in both directions may be transmitted, because the transmissions between PC and STA are cyclic process.

The result of the presented task is the realistically calculated expenditures of WLAN when the high quality telephony services are provided. The results show that the headers of packets of IEEE 802.11 and the additional time intervals increase the technological expenditures and the time of channel occupation. The duration's probabilities of channel occupation for voice conversations in CFP to Gaussian normal distribution are close, in time axis is even, and depend on rate.

The results enable to determine intended for real time communications, general capacity of the channel based on IEEE 802.11 in customer access networks.

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A. Kajackas, L. Pavilanskas. Analysis of the Connection Level Technological Expenditures of Common WLAN Models // Electronics and Electrical Engineering. – Kaunas: Technologija, 2007. – No. 2(74). – P. 63–68.

The investigation of technological expenditures and redundancy in WLAN of IEEE 802.11 standard presented in [8] is preceded. The analysis is extended to connection level of infrastructure networks by fitting them for transmission of real time signals. As known, in packet formation process for each data block transmitted over WLAN the headers of different protocols are appended. By fit allocation of the transmission times the additional time intervals are inserted too. The headers of packets and the additional time intervals increase the technological expenditures and the time of channel occupation. In proceeding, the real time expenditures calculated by reference to conversational speech model, specified in ITU P.59. The result of the presented task is realistically calculated expenditures of WLAN when the high quality telephony services are provided. This enable to determine intended for real time communications, general capacity of the channel. Ill. 7, bibl. 10 (in English; abstracts in English, Russian and Lithuanian).

А. Каяцкас, Л. Павиланскас. Анализ технологических затрат канального уровня в моделях доминирующих технологий WLAN // Электроника и электротехника. – Каунас: Технология, 2007. – № 2(74). – С. 63–68.

Продолжены исследования использования технологических ресурсов и технологической избыточности в сетях стандарта IEEE 802.11, начатые в [8] применительно к канальному уровню сетей с определенной инфраструктурой, когда по сети передаются сигналы реального времени. Как известно, при формировании каждого пакета, к блоку данных присоединяются заголовки различных протоколов. При централизованном распределении между пакетами данных вставляются служебные интервалы времени. Заголовки пакетов, дополнительные временные вставки увеличивают технологические затраты, увеличивают время занятия канала связи. Затраты реального времени вычисляются опираясь на модели телефонного разговора по ITU P.59. Основной результат работы – реалистически рассчитанные затраты канального времени при представлении телефонных услуг высокого качества. Это позволяет определить пропускную способность общего канала, выделенного для передачи сигналов реального времени. Ил. 7, библ. 10 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Kajackas, L. Pavilanskas. Vyraujančių WLAN modelių sujungimų pakopos technologinių sąnaudų analizė // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 2(74). – P. 63–68.

Tęsiami [8] straipsnyje aprašyti technologinių sąnaudų bei perteklumo IEEE 802.11 standarto WLAN tinkluose tyrimai, išplečiant juos į infrastruktūros tinklų sujungimų lygmenį ir pritaikant realaus laiko signalams perduoti. Kaip žinoma, prie kiekvieno WLAN tinklu perduodamo duomenų bloko, formuojant paketą, prijungiamos įvairių protokolų antraštės. Taikant perdavimo laiko paskirstymą, įterpiami ir papildomi laiko intarpai. Paketų antraštės, papildomi intarpai didina technologines sąnaudas, kanalas užimamas ilgesnį laikotarpį. Realaus laiko sąnaudos skaičiuojamos remiantis telefono pokalbių modeliu pagal ITU P.59. Šio darbo rezultatas – realistiškai apskaičiuotos bevielio lokaliojo tinklo kanalo sąnaudos teikiant aukštos kokybės telefonijos paslaugas. Tai leidžia nustatyti bendro kanalo talpą, skirtą realaus laiko perdavimams. Il. 7, bibl. 10 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).