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Call Setup Delays for Voice Communications on IEEE 802.11 Wireless LANs

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Call Setup Delays for Voice Call Establishments over IEEE 802.11 Wireless LANs

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The IEEE 802.11 TGe discusses enhancements to the current Medium Access Control (MAC) protocol in order to provide and manage Quality of Service (QoS) requirements such as voice over IEEE 802.11 wireless LANs. According to the IEEE802.11 standard [1] the MAC sublayer includes a fundamental access method suitable for contention services, the Distributed Coordination Function (DCF), and an optional centralized access method required for contention free services, the Point Coordination Function (PCF). A Basic Service Set (BSS), a group of wireless terminals under the control of DCF or PCF, can either be an independent network or part of an infrastructure network, in which an Access Point (AP) links the wireless terminals to the backbone network, therefore allowing communication between terminals on different BSSs. In DCF mode, the network is in a Contention Period (CP) and the stations compete in order to gain access using the Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA) protocol. In PCF mode, the AP coordinates the medium usage and the network is in Contention-Free Periods (CFP). The medium can be alternated between CP and CFP according to the Contention-Free Period Repetition (CFPR) interval that is the reciprocal of the rate at which the AP initiates the CFP. Following the trend for transferring real-time applications over wireless LANs, we examined how PCF can efficiently be used to carry Constant Bit Rate (CBR) voice traffic between stations of the same BSS, while DCF supports their asynchronous data traffic [2]. The number of voice users supported by PCF can be further increased by using silence detection at each voice user and a new management scheme on the AP's polling list, the so called Cyclic Shift polling process, that does not require any modifications on the wireless terminals access mechanism [3]. In these papers, the voice stations use DCF to set up the call sessions but in our analysis, we focussed on the PCF performance after the call establishment has taken place. Since the call establishment procedure uses a type of signalling protocol, it is essential to examine also its call setup delay.

For calculating the transmission probability of a station in any offered load, we modified the Markov model proposed in [4], which gives results only in saturation conditions, by adding two more states along with the states that describe the backoff mechanism. This modified Markov model is used to estimate the mean delay experienced by a voice station between the instant a call request is created and the time instant this call request is received by the AP, while part of the CFPR interval is devoted to PCF for handling already established calls. Our work assumes a finite number of stations, an error-free channel, no hidden terminal conditions and data packets of constant length.

According to our numerical results, which were found for the high data rate extension of the IEEE 802.11 standard [5], the mean delay of a call request received by the AP may vary from some tens of microseconds to some hundreds of milliseconds depending on many system parameters. The parameters that mainly affect the call setup delay are the number of wireless stations forming the BSS and the total offered load during DCF. Other parameters that affect the system performance are the percentage of CFPR interval used for voice traffic, the used channel bit rate (5.5 and 11 Mbps in IEEE 802.11b standard), the data packet length, the used access method during DCF (the CSMA/CA protocol uses either only acknowledgement messages or the exchange of RTS/CTS frames before transmitting a data frame), the backoff mechanism and the used physical header. The IEEE 802.11b standard proposes two physical headers: a mandatory long physical header that is 192 bits, transmitted at 1 Mbps, and an optional shorter physical header that is divided into two sections, one of 72 bits transmitted at 1 Mbps and a second one of 48 bits transmitted at 2 Mbps. The worst case for the mean call setup delay is met when the network is densely populated and under high load conditions since in this case the number of collided frames increases rapidly. In a no error-free channel, the mean call setup delays have longer durations because of the increased number of retransmissions due to errors. This work highlights the efficiency of DCF for handling call requests when the PCF is used for two-way voice communications.

REFERENCES:

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[2] E. Ziouva, and T. Antonakopoulos, "CBR Packetized Voice Transmission in IEEE802.11 Networks", in Proc 6th IEEE Symposium on Computers and Communications, 2001, pp. 392-398.

[3] E. Ziouva, and T. Antonakopoulos, "Voice Communications over IEEE802.11 Wireless LANs Interconnected Using ATM Links", in Proc. 26^{th} Conference on Local Computer Networks, 2001, pp. 620-629.

[4] G. Bianchi, "Performance Analysis of the IEEE 802.11 Distributed Coordination Function", IEEE Journal on Selected Areas in Communications, vol. 18, no. 3, March 2002, pp. 535-547.

[5] IEEE Std 802.11b, 1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Higher-Speed Physical Layer Extension in the 2.4 GHz Band".

Call Setup Delays for Voice Call Establishments over IEEE 802.11 Wireless LANs

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Outline

- Brief description of IEEE 802.11 networks
- Support of voice communications over IEEE 802.11 networks
- The discrete-time Markov chain model for the mean call setup delay estimation
- Performance evaluation
- Numerical results

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The IEEE 802.11 standard

- A group of wireless terminals forms a *Basic Service Set* (BSS)
- A BSS can either be
  - an independent network or
  - an infrastructure network, in which a station called *Access Point* (AP) links the wireless terminals to a backbone network (like Asynchronous Transfer Mode, ATM), therefore extending their range to other BSSs via other APs

IEEE 802.11 networks: Access procedures

- An IEEE802.11 Basic Service Set may employ:
  - The Distributed Coordination Function (DCF) for asynchronous data transmissions
    - The network is in a Contention Period (CP) where the stations must contend to gain access
  - The Point Coordination Function (PCF) for time-bounded services
    - The PCF uses the AP as a Point Coordinator (PC), which determines the station that has the right to transmit and the network is in a Contention Free Period (CFP)

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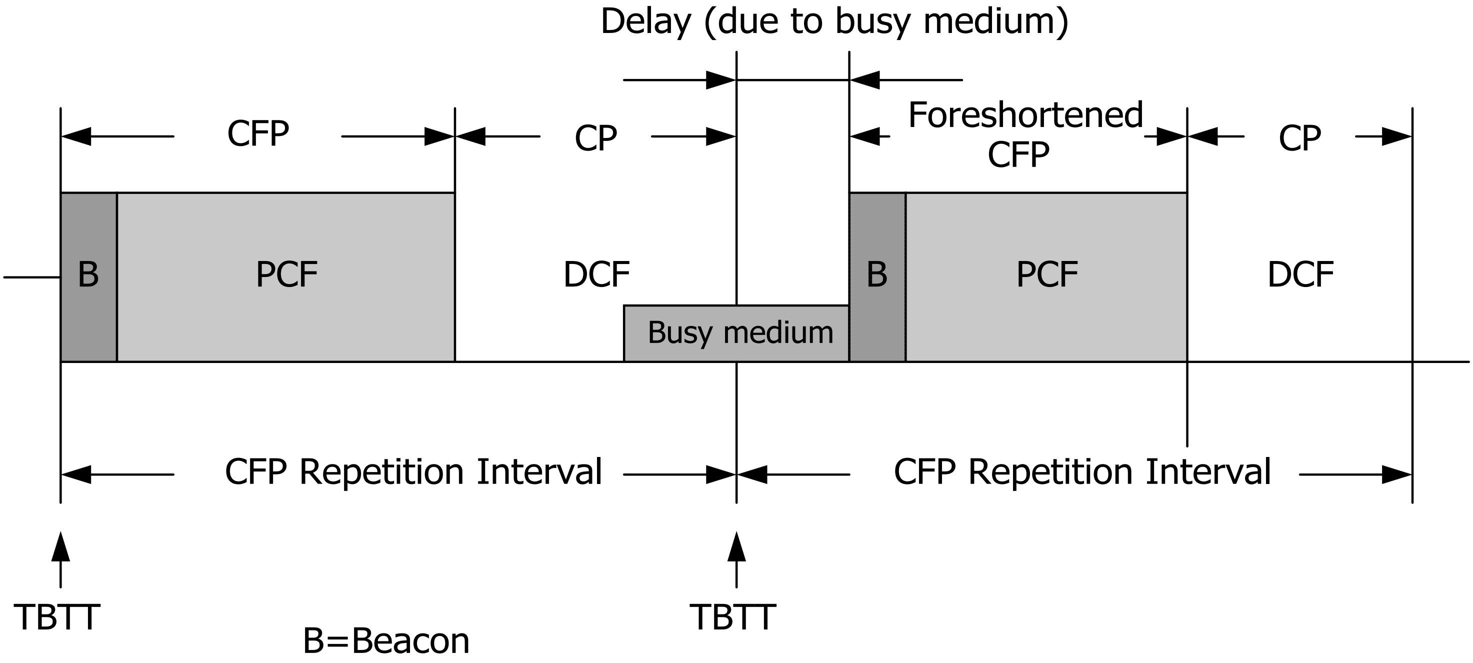
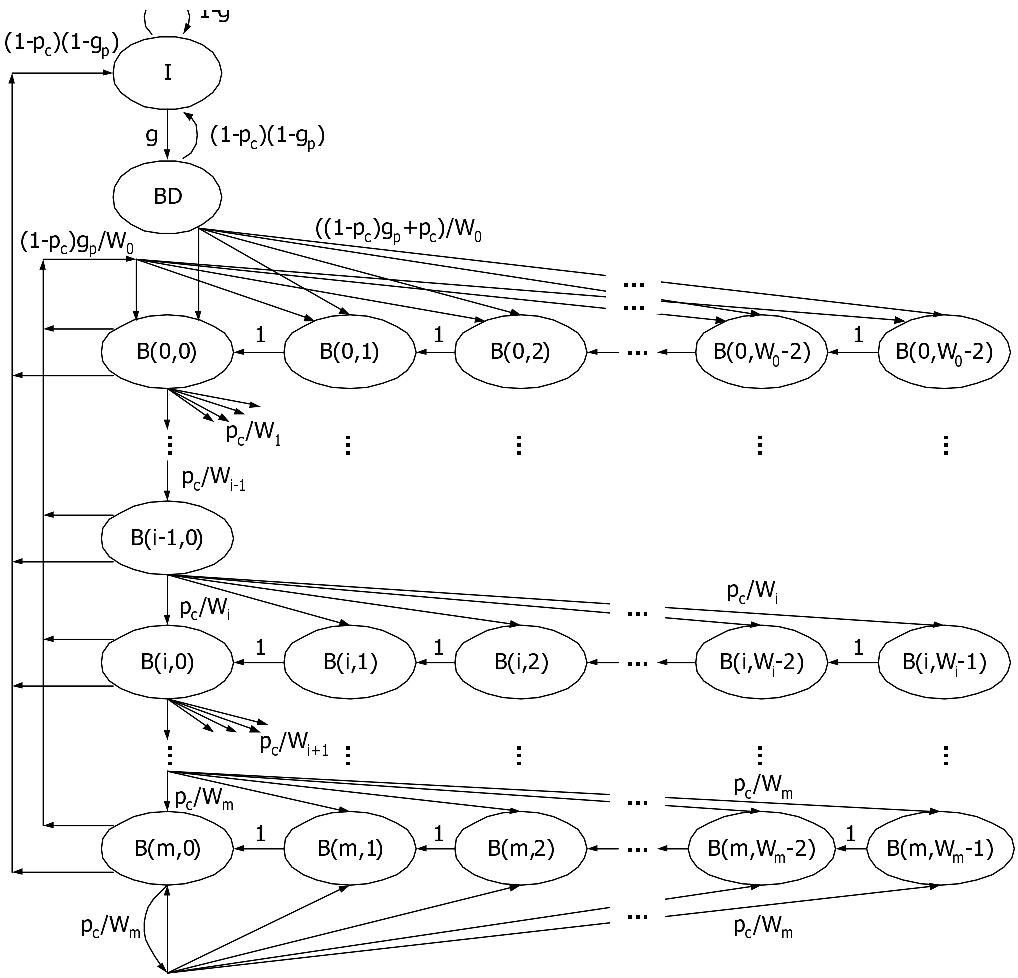
Support of voice communications over IEEE 802.11 networks



The discrete-time Markov chain model for the estimation of the mean call setup delay



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The basic system probabilities

The transmission probability of a station

$$p_t = \frac{2g\left(1-2p_c\right)}{2\left(1-g_p\right)\left(1+g\right)\left(1-2p_c\right)\left(1-p_c\right)+g\left[g_p+\left(1-g_p\right)p_c\right]\left[\left(1-2p_c\right)\left(W+1\right)+p_cW\left(1-\left(2p_c\right)^m\right)\right]}$$

The probability that a transmitted frame collides

$$p_c = 1-\left(1-p_t\right)^{M-1}$$

The probability that a station has a packet arrival or a call request during a slot time

$$g = \min\left(1, \alpha G / M\right)$$

The probability that a station has a packet arrival or a call request during the packet transmission time

$$g_p = \min\left(1, G / M\right)$$

Estimation of the mean call setup delay inside the BSS

$$\overline{D^{BSS}_{CallSetup}} = \overline{D_{CP}} + \left\lceil \frac{\overline{D_{CP}}}{T_{CFPR}} \right\rceil \left(T_{CFPR} - T_{CP}\right)$$

- $\overline{D_{CP}}$: The mean delay of a call request during the contention period
- T_{CFPR}: The duration of the CFPR interval
- T_{CP}: The duration of the contention period

Estimation of the mean delay of a call request during the contention period

$$\overline{D_{CP}} = N_{Col}\left(\overline{D_{access}} + T_{Col}\right) + \overline{D_{access}} + T_{Suc}$$

The number of collisions $$N_{Col} = \frac{1-(1-p_t)^M}{Mp_t(1-p_t)^{M-1}} - 1$$

- D_{access} is the medium access delay that a data packet or a call request experiences due to the used CSMA/CA access protocol and the backoff mechanism
- T_{col} the duration of a collision
- T_{suc} the duration of a successful transmission

Estimation of the mean medium access delay

$$\overline{D_{access}} = \overline{D_{backoff}} + N_{trans}\left[P_{Suc}T_{Suc} + (1-P_{Suc})T_{Col}\right]$$

$$\overline{D_{backoff}} = \frac{\alpha}{6}\Pi\left[B(0,0)\right]\frac{\left[1-p_c-3p_c(4p_c)^m\right]W^2-(1-4p_c)}{(1-p_c)(1-4p_c)}$$

The backoff delay

$$P_{Suc} = \frac{Mp_t(1-p_t)^{M-1}}{1-(1-p_t)^M}$$

The probability the transmission to be successful

The number of transmissions during the backoff mechanism

$$N_{trans} = \frac{\overline{D_{backoff}}}{\max\left(\frac{\alpha(1-p_t)^M}{1-(1-p_t)^M}, \alpha\right)} - 1$$

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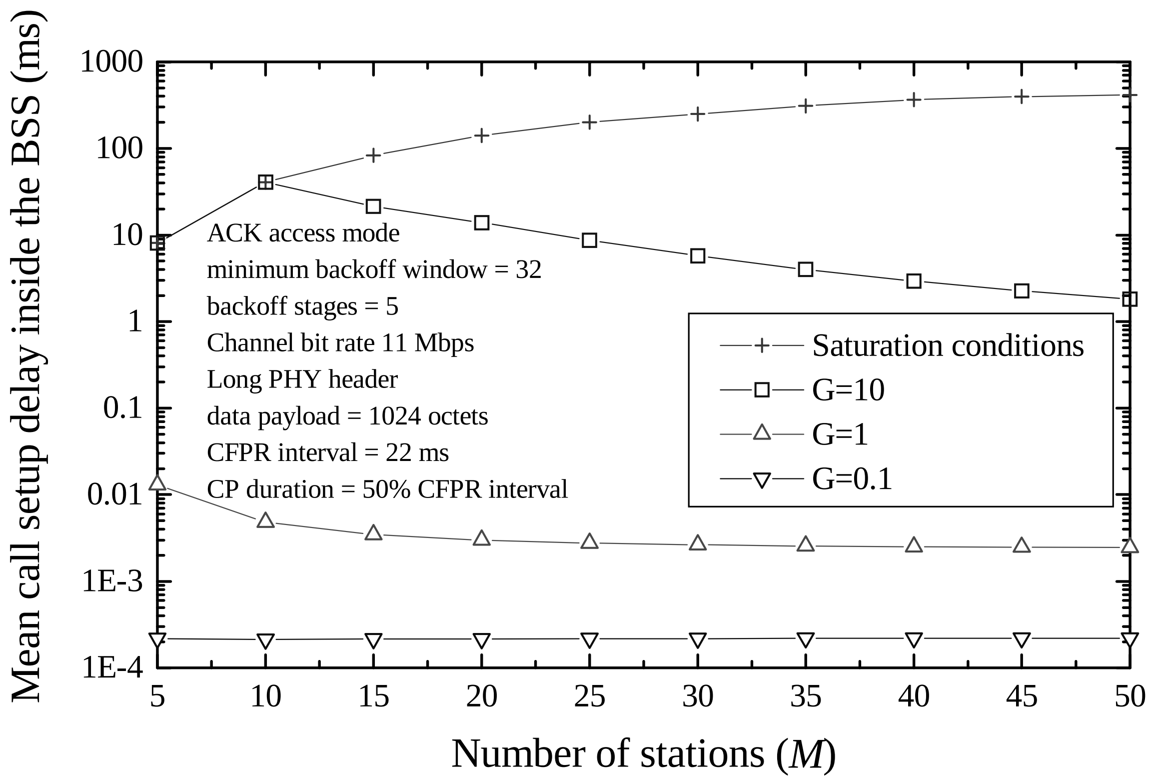
Assumptions

- The number of wireless stations is finite
- The channel is error-free
- No hidden terminal conditions are met
- The data packets are of constant length

The mean call setup delay dependence on the number of stations *M* and the total offered load *G*



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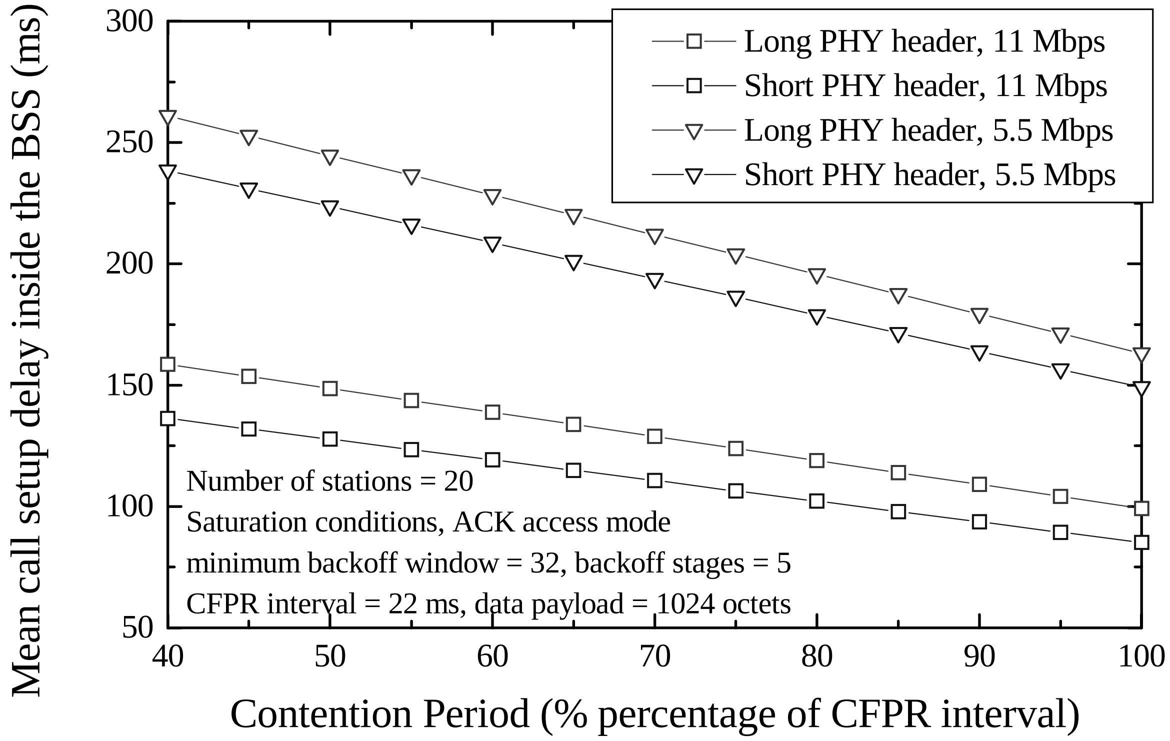
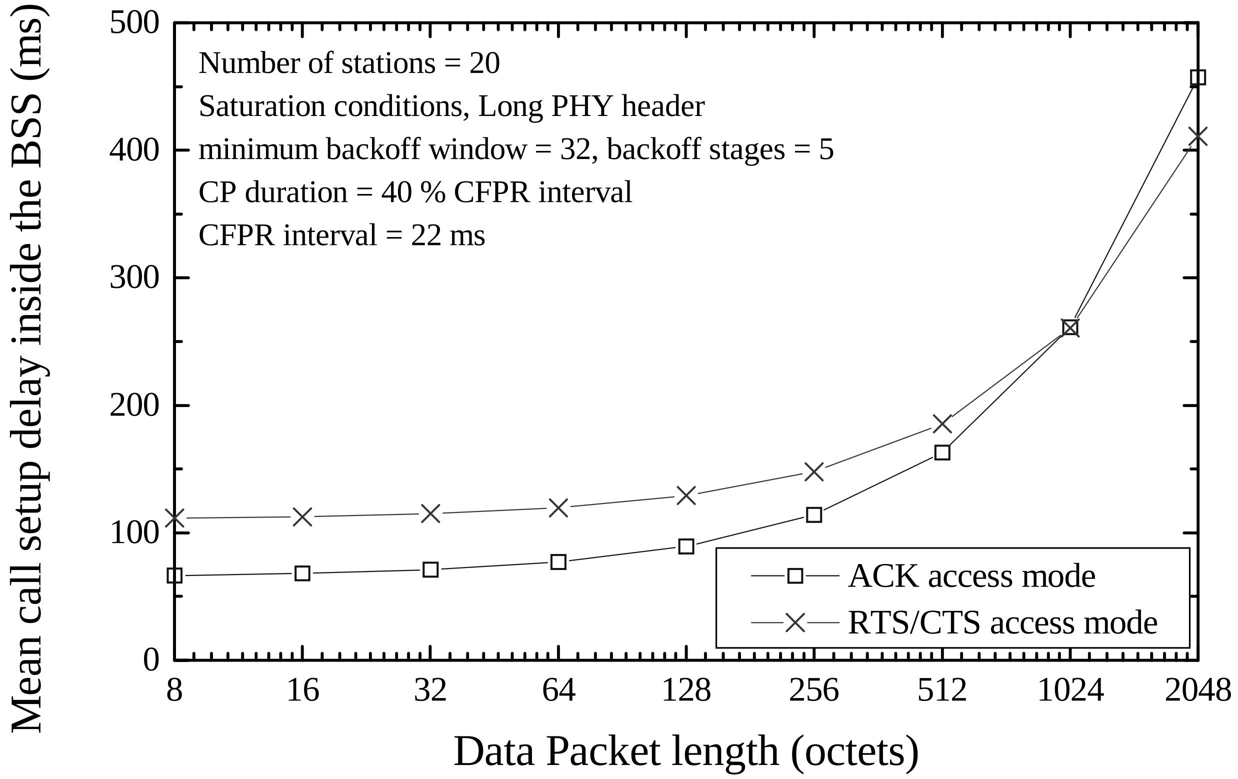
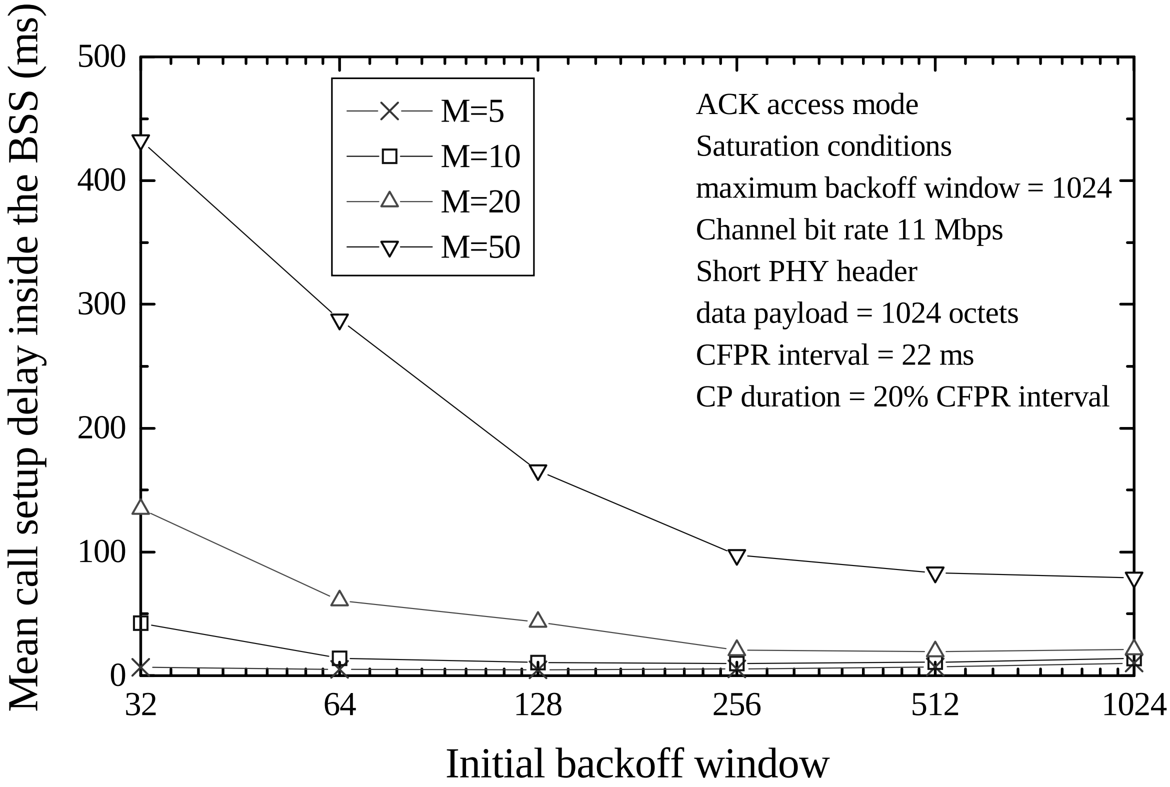
The mean call setup delay dependence on the percentage of CFPR interval used for voice traffic, the channel bit rate and the physical header



The mean call setup delay dependence on the data packet length and the access mode



The mean call setup delay dependence on the backoff procedure



Conclusions

- We presented the estimation of the mean call setup delay inside IEEE 802.11 BSSs, when PCF is used for voice traffic exchanges and DCF for the voice call establishments
- The parameters that mainly affect the call setup delay are the number of wireless stations forming the BSS and the total offered load during DCF
- Other parameters that affect the system performance are the percentage of CFPR interval used for voice traffic, the used channel bit rate, the data packet length, the used access method during DCF, the backoff mechanism and the used physical header
- The worst case for the mean call setup delay is met when the network is densely populated and under high traffic conditions
- If the channel is not error-free, the mean call setup delays have longer durations due to retransmissions.

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