Voice capacity in IEEE 802.11 wireless LANs

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The voice service through IEEE 802.11 wireless LANs is considered and the maximum voice sessions are analysed and simulated for different patterns of voice packet generation based on IEEE 802.11b and 802.11a physical layer characteristics.

Introduction: The support of voice over IP (VoIP) in wireless LANs is a challenging issue because the price of wireless LAN equipment becomes lower and there is no wireless technology to provide such a high data rate like IEEE 802.11a [1] which supports up to 54 Mbit/s. When VoIP is implemented in wireless LANs, the QoS should be guaranteed, where the main constraint is that the packet loss rate should be less than 1% under the constraint of both the access delay bound and retry limit. In this Letter, we evaluate the maximum number of voice sessions in wireless LANs considering both the 802.11b and 11a physical layer specifications [1–4].

VoIP traffic modelling: We consider the G.711 codec for generation of voice packet which has source bit rate of 64 kbit/s. The VoIP packet contains a vocoder frame and many protocol headers. In case of IPv4, the RTP/UDP/IP header is 320 bits (40 bytes) when the header compression is not used. If the header compression is used, the RTP/UDP/IP header are 16 bits. We did not consider the header compression and the voice activity detection (VAD). Therefore, we model the voice traffic as generating (320 + 1280) bits per 20 ms. The structure of VoIP packet in IEEE 802.11 wireless LAN is shown in Fig. 1.

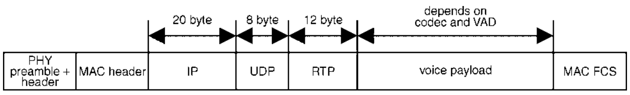

Fig. 1 *VoIP packet in wireless LAN*

We set the delay bound of wireless access for VoIP packets to 20 ms. This allows sufficient delay margin for the backbone network for an end-to-end delay budget.

The QoS of VoIP traffic is defined as the loss rate of voice packets, P_{loss}, is less than 1%. The P_{loss} is defined as follows:

$$P_{loss} = P_{overdelay} + P_{retrylimit} \quad (1)$$

where $P_{overdelay}$ is the dropping probability of the voice packet in the case that the elapsed time for wireless access exceeds a predefined delay bound, and $P_{retrylimit}$ is the discarding probability of the voice packet due to retry limit.

We consider two kinds of voice packet generation. One is the CBR traffic model and the other is the VBR traffic model. In the CBR model, each voice session generates one packet per 20 ms continuously. The VBR traffic uses the ON-OFF model where voice packets are generated only in the ON period. In Brady's VBR model, the ON time and OFF time has exponential distribution with mean of 1 and 1.35 s, respectively.

Each voice session has duplex traffic, i.e. if there are 10 voice sessions, the AP has 10 stations' VoIP packets to transmit. So, the AP has more traffic to transmit than a station.

Maximum capacity in CBR traffic: The maximum capacity of voice traffic is accomplished when there are minimum collisions. Since VoIP packets are generated once an interval, the packet collision can be minimised when the packet accesses are spread.

The necessary time to transmit one voice packet successfully is calculated as follows:

$$T_{one,tx} = T_{aifs} + T_{backoff} + T_{packet} + T_{sifs} + T_{ack} + T_{prodelay} \quad (2)$$

where $T_{one,tx}$ is the minimum transmission time for a VoIP packet to be transmitted successfully, T_{aifs} is the IFS time for the voice packet [2], $T_{backoff}$ is the time needed for the backoff procedure which is dependent on the contention window, T_{packet} is a packet transmission time including physical header and preamble, and T_{ack} is the time required for ACK packet transmission.

The packet transmission time, T_{packet} in IEEE 802.11b and 11a is expressed as follows:

$$T_{packet,11b} = T_{PhyHdr} + \text{ceiling}((M_{hdr} + M_{payload} + M_{FCS})/Rate) \quad (3)$$

$$T_{packet,11a} = T_{PhyHdr} + \text{ceiling}((16 + M_{hdr} + M_{payload} + M_{FCS} + 6)/N_{DBPS}) \times N_{DBPS}/Rate \quad (4)$$

where the ceiling is a function that returns the smallest integer value greater than or equal to its argument value and N_{DBPS} is the data bits per OFDM symbol [3]. The other symbols are shown in Table 1.

Table 1: Parameters used in IEEE 802.11 MAC and PHY

Parameters	Symbol	11b PHY	11a PHY
Slot time	T_{slot}	20 µs	9 µs
SIFS time	T_{sifs}	10 µs	16 µs
DIFS time	T_{difs}	50 µs	34 µs
AIFS time	T_{aifs}	30 µs	25 µs
Maximum data rate	$Rate$	11 Mbit/s	54 Mbit/s
PHY preamble + header transmission time	T_{PhyHdr}	192 µs	20 µs
Propagation delay	$T_{prodely}$	1 µs	1 µs
Delay bound	$T_{delaybound}$	20 µs	20 µs
MAC header size (including QoS Field)	M_{hdr}	32 bytes	32 bytes
FCS size	M_{FCS}	4 bytes	4 bytes
Payload size	$M_{payload}$	Variable	Variable

The maximum number of voice sessions is the maximum integer value of $N_{v,max}$ satisfying the following equation:

$$N_{v,max}(T_{one,tx} + T_{one,tx} - T_{backoff})\left(1 + \sum_{j=1}^{Retrylimit} P_{c;j}\right) \leq 20 \text{ ms} \quad (5)$$

where $T_{backoff}$ is the idle time for backoff procedure, the average value of which is the $CW/2{*}T_{slot}$ and $P_{c,j}$ is the probability of successive jth collisions. We have the simplicity that $P_{c,j} = (1/CW)^j$ in the case that CW is fixed.

Since the voice session is duplex traffic, the downlink (AP-to-STA) voice packets are always in the queue at full load. Approximately, we assume that the uplink (STA-to-AP) voice packets are spread and those are collided with downlink packets. In that case, the average backoff time, $T_{backoff}$, is applied to only one-way traffic because the backoff timers of downlink and uplink packets are simultaneously decreased. To satisfy the delay bound, the generated voice packets during 20 ms should be transmitted within 20 ms.

In the case of the VBR model, the generated VoIP packets are decreased since the VoIP packet is generated only during the ON interval. The maximum number of voice session is also increased.

Simulation results: We simulated the voice capacity in IEEE 802.11 wireless LANs through OPNET simulation tool. We used G.711 codec and considered no header compression. The delay bound for the wireless access is 20 ms. We considered the 802.11b and 11a physical layer specification and the used parameters are shown in Table 1.

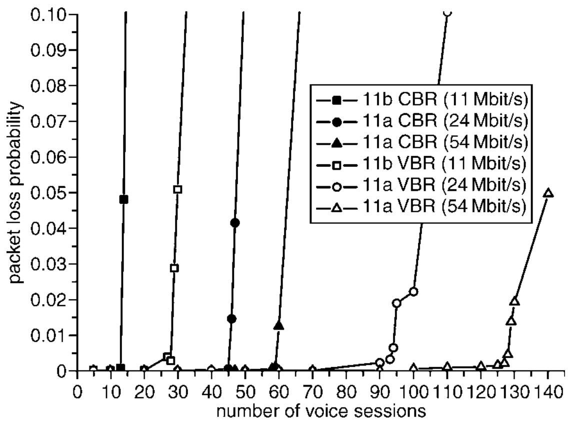

Fig. 2 *Packet loss probability against number of voice sessions*

The QoS constraint for the voice sessions is that the total packet loss rate is less than 1%. The packet loss can occur when the retransmission number of collided packet exceeds the predefined retry limit and the delay of wireless access is over the delay bound.

The packet loss rates according to the number of voice sessions are shown in Fig. 2 where the *CW* is fixed to 16. The packet loss rate increases sharply beyond the maximum capacity which means that the QoS of voice traffic is degraded severely if only one voice session could be added when the maximum number of voice sessions is serviced. According to the *CW* value, the maximum capacity varies because the backoff time and collision probability are affected by *CW*. The optimal *CW* value could be found as further work.

Table 2: Maximum number of voice sessions (A:analysis results)

PHY (data rate)	CBR model			ON-OFF VBR model		
	CW = 8	CW = 16	CW = 32	CW = 8	CW = 16	CW = 32
11b (11 Mbit/s)	13(A:13)	13(A:13)	12(A:12)	26	28	25
11a (24 Mbit/s)	46(A:46)	45(A:45)	40(A:40)	90	94	85
11a (54 Mbit/s)	61(A:62)	59(A:59)	50(A:50)	125	127	109

The maximum number of voice sessions are summarised in Table 2. The numerical results of the proposed analysis method are very close to the maximum number in the case of CBR traffic. In the VBR model, the maximum number is close to $(1 + 1.35)$ times of that of the CBR model, which is the ratio of the ON period.

Conclusions: We evaluated the maximum voice sessions in IEEE 802.11 wireless LANs. With 11b PHY, only 13 voice sessions are supported without any other data transmissions, which is insufficient to provide public voice services. However, 61 and 127 voice sessions can be provided when the CBR and VBR models are used with 11a PHY, respectively.

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