Modeling 802.11e for data traffic parameter design

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TCP Uploads

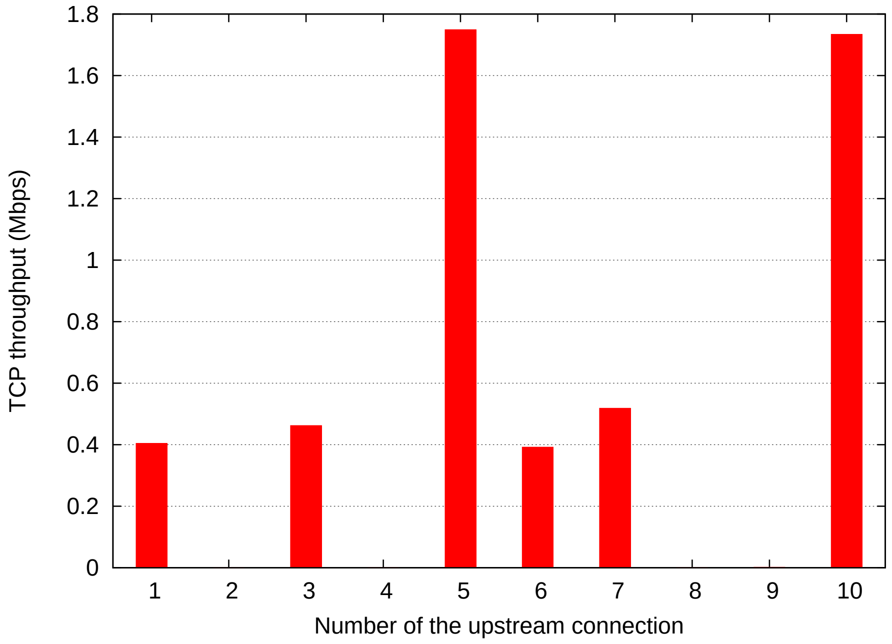


Figure 1: Competing TCP uploads, 10 stations (NS2 simulation, 802.11 MAC, 300s duration).

Existing literature

Empirical studies.

- Q. Ni and L. Romdhani and T. Turletti, Wirel Commun Mob Com 5:4 (2004).
- P. Gopalakrishnan, D. Famolari and T. Kodama, Proc. IEEE GLOBECOM (2004).
- Y. Xiao and H. Li and S. Choi, Proc. IEEE INFOCOM (2004).

Saturated 802.11e multi-class models.

- R. Battiti and Bo Li, University of Trento Technical Report DIT-03-024 (2003).
- J.W. Robinson and T.S. Randhawa, IEEE JSAC 22:5 (2004).
- Z. Kong, D. H.K. Tsang, B. Bensaou and D. Gao, IEEE JSAC 22:10 (2004).

Contribution

- multi-class 802.11e EDCF finite-load model,
- simple enough to be solvable,
- accurately predicts the throughputs of unsaturated traffic,
- can model all of TXOP, AIFS and $\mathrm{CW}_{\mathrm{min}}$,
- is applied to choose parameters to restore TCP upload fairness.

The 802.11e MAC

- After transmission counter initialized to uniform integer in $[0, CW - 1]$.
- Medium determined idle if idle for period DIFS.
- Counter decremented once for each slot that the medium is idle.
- Countdown halts if medium busy; resumes after DIFS.
- If packet arrives before counter reaches zero, station transmits for max duration TXOP (one packet without 802.11e).
- If packet arrives after countdown completed, the station senses the medium. If medium idle, the station transmits; if busy, another back-off counter is chosen.
- If > 2 stations transmit simultaneously, a collision occurs. Colliding stations double their CW (up to a maximum value), select a new back-off counter uniformly and the process repeats.
- After successful transmission, CW is reset to its minimal value $\mathrm{CW}_{\mathrm{min}}$ and a new countdown starts regardless of the presence of a packet at the MAC.

The 802.11e MAC enables the values of $DIFS$ (called AIFS in 802.11e), $\mathrm{CW}_{\mathrm{min}}$ and TXOP to be set on a per-class basis for each station. That is, traffic is directed to up to four different queues at each station, with each queue assigned different MAC parameter values.

The standard suggests parameter values for four classes: best effort, voice, video and background. It also allows the AP to assign parameters to queues on stations.

Finite load 11b

K.D., D.M., D.L., RAWNET (2005), Comms Letters (2005), ToN (2007).

Complications:

- Post-backoff.
- Relating real offered load to non real time Markov chain.
- Queueing issues due to non real time service model.

Can cope with $\mathrm{CW}_{\min}$ and $TXOP$, but not different $AIFS$.

Matching Offered Load

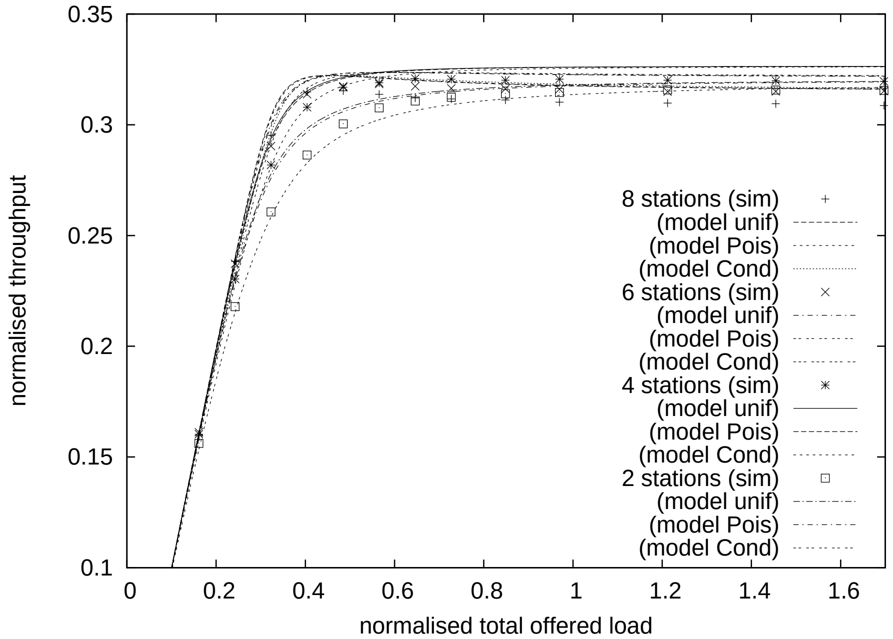


Figure 2: Throughput as the traffic arrival rate is varied. Results for the three load relationships.

Finite load 11e

Added complications:

- Need hold states for $AIFS$.
- New, different coupling equations.

$$P_{\mathrm{h}} = \frac{(1 - \prod_{j=1}^{n_1}(1-\tau_j^{(1)}) \prod_{j=1}^{n_2}(1-\tau_j^{(2)})) \sum_{i=1}^{D} P_{S_1}^{-i}}{1 + (1 - \prod_{j=1}^{n_1}(1-\tau_j^{(1)}) \prod_{j=1}^{n_2}(1-\tau_j^{(2)})) \sum_{i=1}^{D} P_{S_1}^{-i}}. \quad (1)$$

Some equations

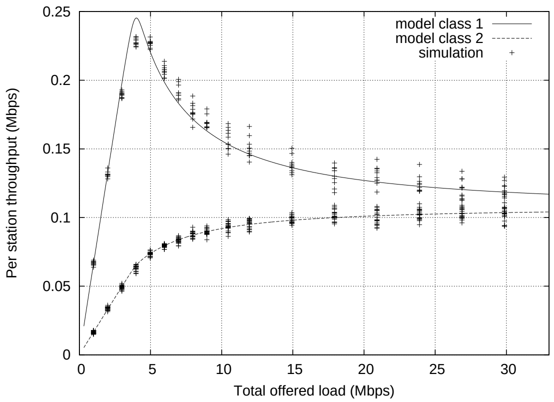
$$1 - p_i^{(1)} = \prod_{j \neq i} (1 - \tau_j^{(1)})(P_\mathrm{h} + (1 - P_\mathrm{h}) \prod_{j=1}^{n_2} (1 - \tau_j^{(2)})) \tag{2}$$

$$1 - p_i^{(2)} = \prod_{j=1}^{n_1} (1 - \tau_j^{(1)}) \prod_{j \neq i} (1 - \tau_j^{(2)}). \tag{3}$$

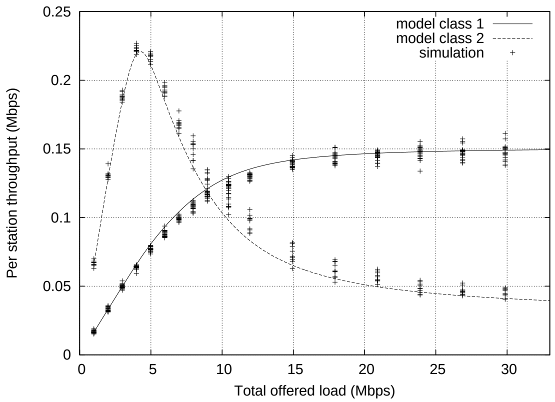
Similar expressions for calculating expected state lengths.

$$8E\lambda = \frac{-\log(1-q)8E}{E_s} \text{ Mbps.} \tag{4}$$

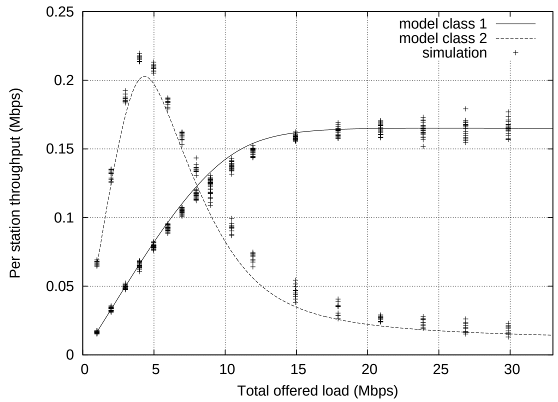
How good is it?



(a) $D = 0$



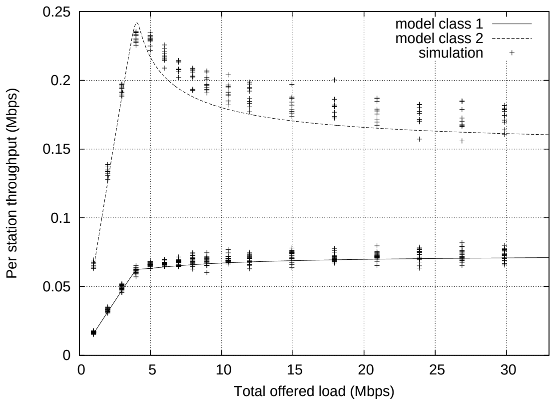
(b) $D = 2$



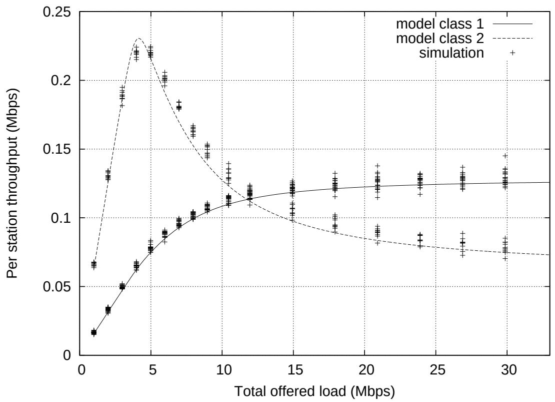
(c) $D = 4$

Throughput for a station in each class vs. offered load. 10 class 1 stations offering one quarter the load of 20 class 2 stations. Range of D values, the difference in AIFS between class 2 and class 1 (NS2 simulation and model predictions, 802.11e MAC, 11Mbps PHY, 100s duration.).

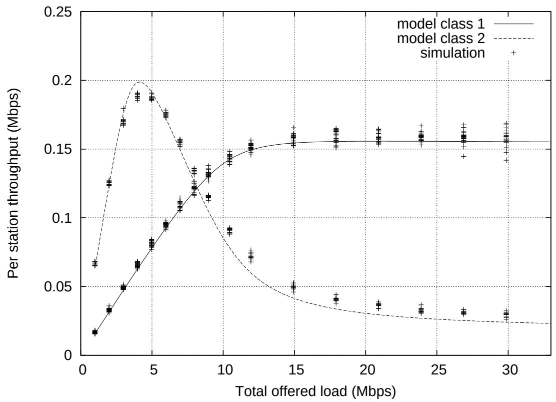
How good is it?



(d) $W_0^{(1)} = 32$, $W_0^{(2)} = 16$



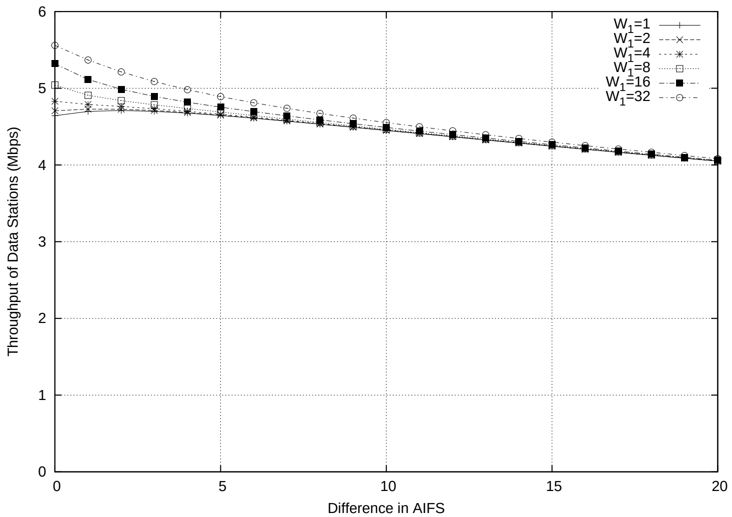
(e) $W_0^{(1)} = 32$, $W_0^{(2)} = 64$



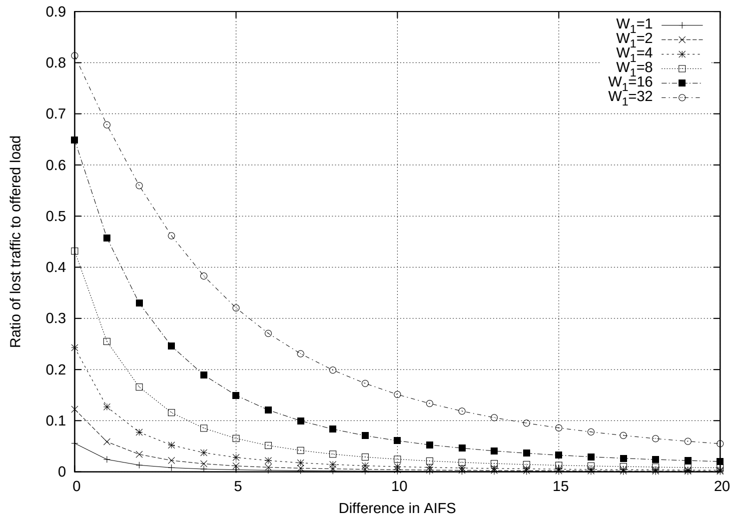
(f) $W_0^{(1)} = 32, W_0^{(2)} = 256$

Throughput for a station in each class vs. offered load. There are 10 class 1 stations each offering one quarter the load of 20 class 2 stations. Range of $\mathrm{CW}_{\min}$ values (NS2 simulation and model predictions, 802.11e MAC 11Mbps PHY, 100s duration).

How do you use it?



(g) Data throughput

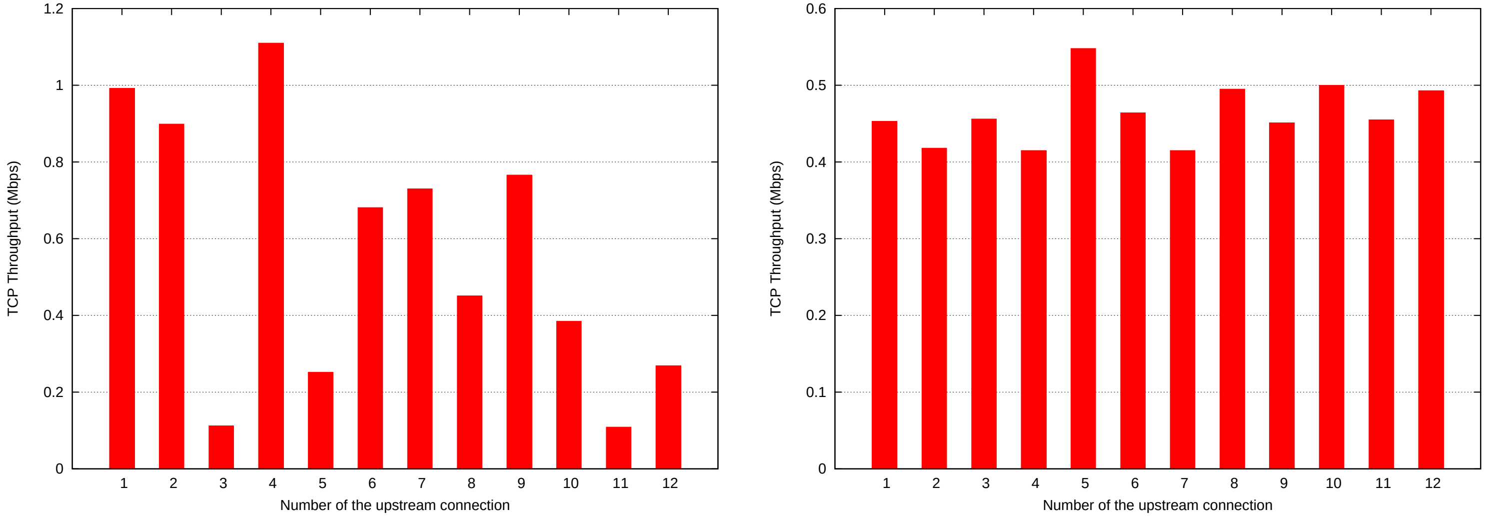


(h) ACK loss

10 stations (1500 byte packets) and AP transmitting (60 byte packets) at half achieved data rate (Model predictions, 802.11e MAC, 300s duration).

Aim for 1%: $(\mathrm{CW}_{\min}, \mathrm{AIFS})$ = (1,2), (2,4), (4,7), (8,12), . . .

Does it work?



Competing TCP uploads, 12 stations **experiment** without and with prioritization (802.11e MAC, 300s duration).

Conclusions

- 802.11e CSMA/CA model that is simple, solvable, yet complex enough to predict data throughput.
- Model gives insight into effect of 802.11e parameters.
- Prioritization schemes can now be designed analytically.
- Have applied model to voice.
- Future: applications to mesh.