An Effective Capacity Estimation Scheme in IEEE802.11-based Ad Hoc Networks

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ABSTRACT

Capacity estimation is a key component of any admission control scheme required to support quality of service provision in mobile ad hoc networks. A range of schemes have been previously proposed to estimate residual capacity that is derived from window-based measurements of channel estimation. In this paper a simple and improved mechanism to estimate residual capacity in IEEE802.11-based ad hoc networks is presented. The scheme proposes the use of a 'forgiveness' factor to weight these previous measurements and is shown through simulation-based evaluation to provide accurate utilizations estimation and improved residual capacity based admission control.

Keywords: admission control, capacity estimation, mobile ad hoc networks, quality of service.

1. Introduction

Capacity estimation is a key component in the provision of quality of service (QoS) in mobile ad hoc networks (MANETs) [1]. However, accurate capacity estimation can be difficult because each host has only imprecise knowledge of the network status, thus, an effective estimation scheme is highly desirable. Many previously proposed schemes [2-5] adopt "Listen"-based estimation techniques derived from IEEE 802.11 MAC/PHY specification [6]. The "Listen" scheme requires each node to listen to the channel and estimate the residual or unused capacity of the link based on the measurement of the local channel utilization. At any specific instant in time, a link is either transmitting a packet at the full link capacity or it is idle, hence the instantaneous utilization of a link can only be either 0 or 1. Therefore, residual capacity requires time averaging of the instantaneous utilization over the time interval of interest. The average utilization $(u(t))$ for a time period $(t-w,t)$ is given by [7,8]

$$u(t) = \frac{1}{w}\int_{t-w}^{t} f(t).dt \quad (1)$$

where $(f(t))$ is the channel activity function or the instantaneous residual capacity of the link at time (t). We refer to the time window (w) as the averaging timescale of the residual capacity. The accuracy of the residual capacity estimation depends on the value of window (w). When the window is too small, the measure will not reflect accurately the overall channel activity, i.e., if the channel was only busy or free momentarily; while if the window is large then the utilization measure will contain historic but possibly redundant traffic during the route selection process thus reducing the overall network performance. To operate effectively, the window over which the integration is done must be chosen to balance these conflicting constraints. The choice of window size for appropriate capacity estimation is a major impediment to such window-based schemes and it is this aspect that is addressed in this paper.

The rest of the paper is organized as follows: Section 2 describes the forgiven capacity estimation scheme. In Section 3, the simulation environment is presented. Simulation results are presented in Section 4 and concluding remarks are made in Section 5.

2. Forgiven residual capacity estimation scheme

A simple residual capacity estimation scheme with a lower reliance upon window size is proposed [9] whereby the channel activity function $(f(t))$ is multiplied by a weighting function $(g(t))$ as described below:

$$u(t) = \frac{1}{w}\int_{-w}^{0} f(t).g(t)\,dt \tag{2}$$

and

$$g(t) = \begin{cases} 1 & |t| \le (w/2) - \Delta t \\ \frac{1}{2}\left[1 + \sin\left\{\frac{\pi}{2}\left(1 - \frac{|t|}{w/2}\right)\frac{w/2}{\Delta t}\right\}\right] & (w/2) - \Delta t < |t| < (w/2) + \Delta t \\ 0 & |t| \ge (w/2) + \Delta t \end{cases} \tag{3}$$

where $g(t)$ make use of the raised cosine filter characteristics [10] widely used in digital communication systems for pulse shaping and Δt is the excess (absolute) time. The normalized excess time, τ, given by

$$\tau = \frac{\Delta t}{w/2} \tag{4}$$

is called the 'forgiveness factor' or the 'roll-off factor' and can take any value between 0 and 1. The scheme can be said as a 'forgiven' capacity estimation scheme. Figure 1 shows the weighting function $(g(t))$ for several values of the forgiveness factor (τ) at *w*=0.5 and an example of the weighted channel activity for *w*=0.5 and *τ*=1 is shown in Figure 2. When $\tau = 0$, the scheme can be referred to as an 'unforgiven' capacity estimation scheme but for half of the window size. The value of *τ* can be determined through testing to obtain a good estimation of utilization such that it can give more emphasis to the recent information rather than the past information over a time window (*w*).

Given the local channel utilization (*u*(*t*)) and the maximum achievable channel capacity (C_{max}), the local residual capacity (C_{res}) is estimated using the following equation [7,8]:

$$C_{res} = (1 - u(t)).C_{\max} \tag{5}$$

where 0 ≤ *u*(*t*) ≤ 1 is a measure of the channel utilization.

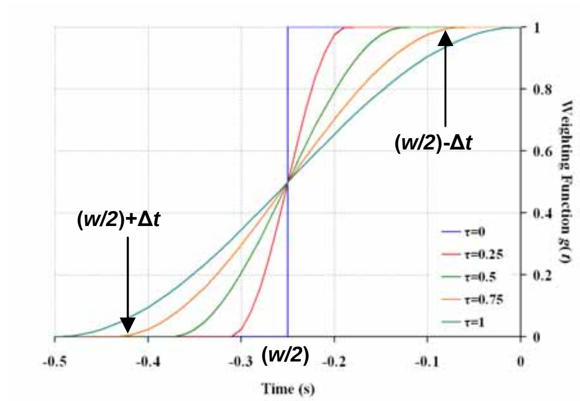


Figure 1. Illustration of forgiveness factor (*w*=0.5).

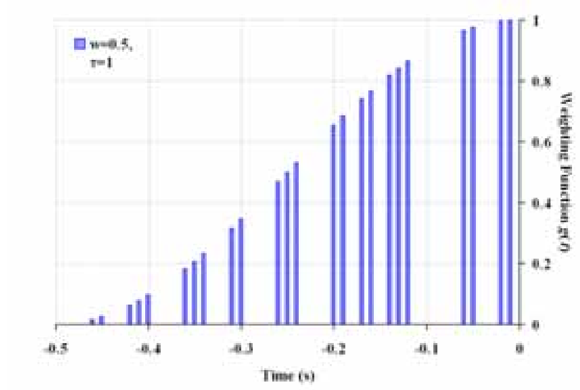


Figure 2. Example of the weighted channel activity for *w*=0.5 and *τ*=1.

3. Simulation environment

In order to evaluate the forgiven residual capacity estimation scheme, a novel and practical QoS routing scheme referred to as the QoS-aware Shortest Multipath Source (Q-SMS) routing scheme is used [8]. Q-SMS modifies and extends the route discovery and maintenance of SMS routing scheme [11] to provide QoS assurance. The QoS extension allows nodes to use their estimation of the residual capacity to make better admission control decisions. The network simulator

NS-2.33 [12] is used to execute the proposed scheme. The simulation environment consists of 50 wireless nodes forming an ad hoc wireless network, moving over a 700 x 500 m^2 flat space. The physical radio model uses the characteristics of the 914MHz Lucent WaveLAN DSSS radio with minimal range of 250m and nominal bit rate of 11Mbps. However, the maximum achievable capacity (C_{max}) of 11 Mbps system is just 4.24 Mbps [13].

Both Constant Bit Rate (CBR) and Variable Bit Rate (VBR) are considered as traffic sources to analyze the contending schemes. VBR traffic is established between nodes using an exponential ON/OFF traffic generator [12]. The number of active sources is 20 nodes, chosen randomly from the full set of nodes generating 512 byte data packets. The network load (traffic intensity) is varied by changing the rate of the active sources. Mobility is characterized by speed randomly distributed between 0-10 m/s following the random waypoint model with a pause time of 30 seconds. Simulations are run for 900 seconds of real time. Each data point represents an average of twenty runs using different seeds with the corresponding confidence interval of 95% [14,15]. The overall simulation parameters are summarized in Table 1.

Parameter	Value
NS-2 Version	2.33
Transmitter range	250m
Nominal channel BW	11Mbps
Simulation time	900sec
Number of nodes	50
Pause time	30sec
Terrain size	700x500m^2
Traffic type	CBR and VBR
Packet rate	22-30 packets/sec
Packet size	512 bytes
Number of sources	20
Maximum speed	0-10 m/s
No. of runs	20
Window size	0.125, 0.25, 0.5, 0.75 and 1.0
Forgiveness factor	0, 0.25, 0.375, 0.5, 0.625, 0.75 and 1.0

Table 1. Simulation parameters.

4. Results and discussion

First simulation-based experiments are conducted to evaluate the improvements offered by Q-SMS without the forgiven estimation scheme and contrasted with SMS which has no QoS support. The accuracy of the available capacity estimation depends on the value of window (*w*). A window ranging from small to relatively large is considered to see the affect on the performance of Q-SMS scheme. Figure 3 shows the impact of varying window size depicting the ratio of the average delay of Q-SMS to SMS average delay for average packet rate (between 22 and 30 packets per second). Slightly better performance was observed for a small window (*w*=0.25) and relatively low performance was recorded for large windows for the reasons explained in the Introduction section.

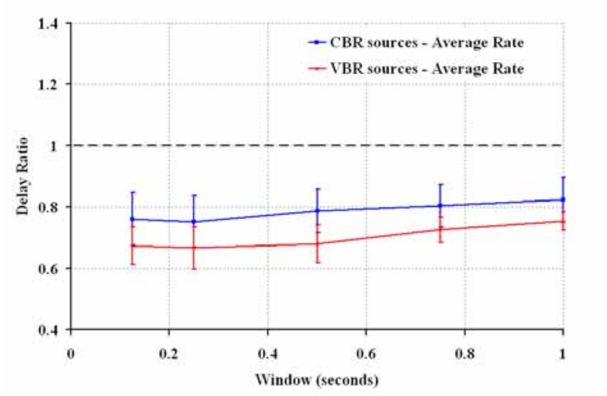
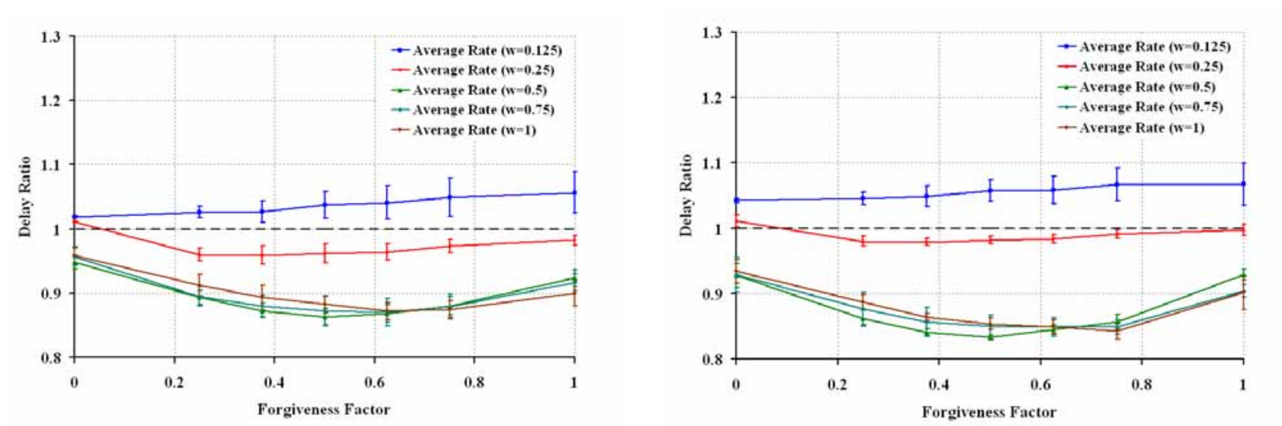


Figure 3. Average end-to-end delay ratio of Q-SMS to SMS versus window size for average packet rate.

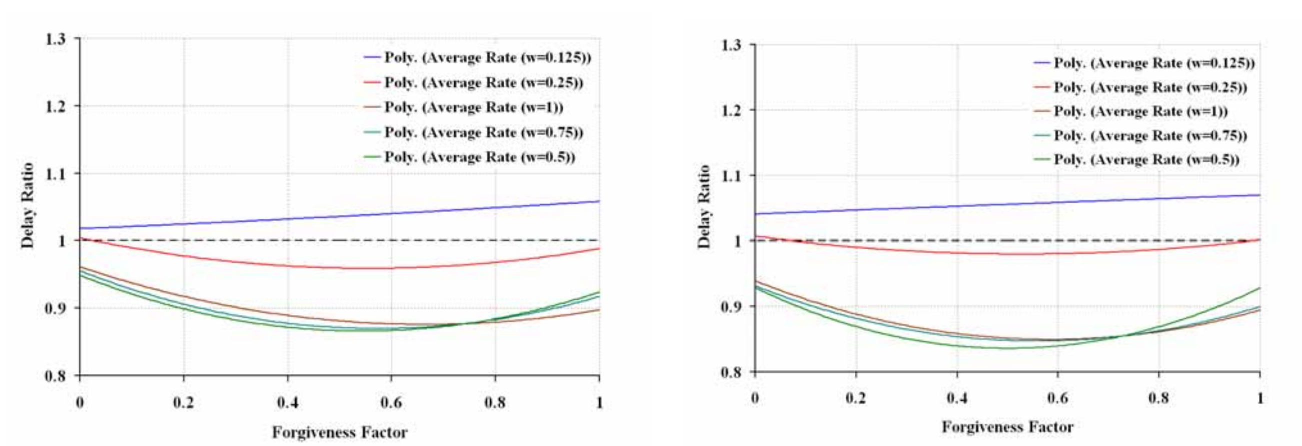
The second part of the experimental work evaluates Q-SMS with 'forgiven' capacity estimation (here referred as Q-SMS-F) and compares with Q-SMS (which performs capacity estimation with no weighting function) to benchmark any difference that results from a change in the window size. To maintain uniformity, the parameters used with Q-SMS-F remain the same as in the Q-SMS case. Figure 4(a) and Figure 4(b) present the impact of varying the forgiveness factor for different window sizes with CBR and VBR traffic sources respectively and shows the relative delay performance of the network of the two schemes whereby delay ratio is simply the ratio of the average delay of Q-SMS-F compared to Q-SMS average delay for average packet rate. The graph is further plotted in terms of the best fit line as shown in Figure 5 in order to look at the general trend.

From Figure 4 and Figure 5, it can be clearly seen that the Q-SMS-F offers improvement for window sizes of *w*=0.5, 0.75 and 1 for both CBR and VBR sources. It was also observed that there is an impact of the forgiveness factor with respect to the window size. The optimum value of the forgiveness factor for corresponding window size depicted from the graphs shows a linear relationship between the two parameters (Figure 6). It is evident that the improvement in the network performance is consistent for the mentioned range of window sizes and forgiveness factors. It can be concluded that Q-SMS-F is a simple and effective mechanism that has no high sensitivity to window size.



(a) CBR sources (b) VBR sources

Figure 4. Average end-to-end delay ratio of Q-SMS-F to Q-SMS versus forgiveness factor for average packet rate.



(a) CBR sources (b) VBR sources

Figure 5. Best fit curves - average end-to-end delay ratio of Q-SMS-F to Q-SMS versus forgiveness factor for average packet rate.

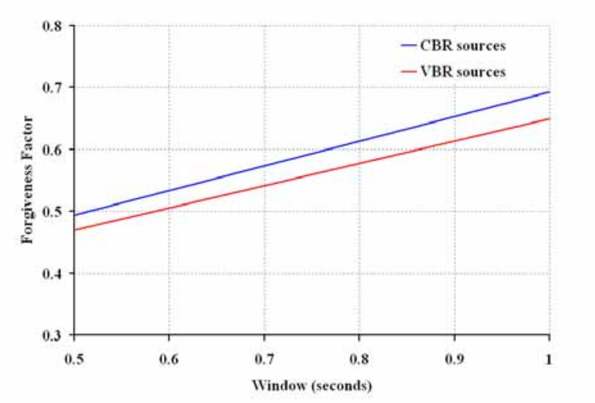


Figure 6. Relationship between window size and forgiveness factor.

5. Conclusion

The paper introduces a simple residual capacity estimation technique (Q-SMS-F) that has less dependence on the window size. The scheme proposes the use of a 'forgiveness' factor to weight these previous measurements to provide appropriate utilizations estimation and improved available capacity based admission control. Results justify that Q-SMS-F is a simple and effective mechanism that has no high sensitivity to window size and offer improvements over Q-SMS scheme in the changing environment of MANETs.

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