system behavior, as well as from the results presented in the section **??**.

Algorithm 2 Load Control Algorithm

if $\{P_{L(lo)} \leq P_L \leq P_{L(up)}\}$ **then**
 (RULE #1)
 $\omega_j = \omega_j + f;\ j = (n_c, k_c - 1)$
 $\omega_i = \omega_i + f;\ i = (\frac{\overline{n}}{\overline{k}}(k_c + 1), k_c + 1)$
 $(\overline{n}, \overline{k}) \approx (n_c, k_c)$
 subject to: $2k_c \leq n_c \leq 4k_c$
else if $\{P_L \geq P_{L(up)}\}$ **then**
 (RULE #2)
 $\omega_j = \omega_j + f;\ j = (k_c, n_c)$
 $k_c = \min\{(\overline{k} - (\overline{k} - k_{min}) * d, k_{min})\}$
 if $k_c \neq k_{min}$ **then**
  $n_c = (\overline{n}/\overline{k}) * k_c$
 else
  $n_c = \max(n_c - 1, n_{min})$
 end if
 subject to:
 if $G_{est} \leq G_{peak}$ **then**
  $3k_c \leq n_c \leq 4k_c$
 else
  $2k_c \leq n_c \leq 4k_c$
 end if
else if $\{P_L \leq P_{L(up)}\}$ **then**
 (RULE #3)
 $k_c = \min(k_c + 1, k_{max})$
 $n_c = (\overline{n}/\overline{k}) * k_c$
 subject to: $2k_c \leq n_c \leq 4k_c$
end if

The choice for the numerical values used with the Algorithm **??** is detailed in Table **??**.

Description	Parameter	Value
Min info size	k_{min}	1
Max info size	k_{max}	10
Min code length	n_{min}	1
Max code length	n_{max}	15
LC chosen k	k_c	$[k_{min}, k_{max}]$
LC chosen n	n_c	$[n_{min}, n_{max}]$
G peak threshold	G_{peak}	0.80
P_L tuning factor	M	0.005
Initial $P_{L(up)}$ value	$P_{L(up)}$	0.03
Initial $P_{L(lo)}$ value	$P_{L(lo)}$	0.01
Ω_i at t=0	Ω_i^0	$1/length(C)$
Control interval	LC_p	3s
Window duration	w_d	3s

Table 3. Simulation and tuning parameters for the LC algorithm

4. Numerical Results

The previous section describes the mathematical framework behind the GE-CRDSA. The algorithm allows the users to randomly choose the number of information and parity packets by using the PMF $\Omega_{(n,k)}$.

In this section, by exploiting the simulation results, it is shown how the PMF, and consequently the choice of (n_c, k_c), affects the throughput and the packet loss for different G values.

An ad-hoc simulator has been developed to test the two algorithms. The system and simulation parameters for the satellite scenario are summarized in Table **??**.

Parameter	Value
Bandwidth	8 Mhz
Modulation	QPSK
Phy FEC	1/3
Frame Duration	0.026s
N_s (slots)	100
IC max iterations[2]	20

Table 4. Simulation parameters for the case study

The simulation results are here presented. The LC technique and CE control strategy are compared, initially by forcing them to use the same set of linear codes C, detailed in table **??**. Figures **??** and **??** show the case of increasing G, while Figures **??** and **??** the decreasing one. A random G fluctuation can be obtained from those two profiles. In fact, a real G profile usually exhibits slower variations than those presented here. It is worth noting that the LC outperforms that based on CE theory in terms of throughput at G between 0.6 and 0.4, while the two control techniques show comparable behaviors at other loads.

In Figure **??**, throughput and packet loss are shown for a larger set of codes C, upper bounded by n_{max} and k_{max}, as in Table **??**. In fact, the LC technique is not limited by an a priori information request. Therefore whatever C is, it slowly adjusts the Ω in the described way. On the other hand, the CE Control Strategy (CECS) offers the possibility to immediately use the Ω showing the highest throughput at that G value, because of the heuristic. The LC and CE algorithms use a different codes distribution at each load level. If you refer to $(\overline{n}, \overline{k})$ plots, it is possible to see how the same throughput value can be reached using a different PMF. In Figure **??**, it is also possible to view $P_{L(up)}$ and $P_{L(low)}$ values and how the P_L value is bounded within, for G from 0.7

[2]The interference cancellation (IC) process performs several iterations in order to recover the maximum number of packets from the collision set in each frame. A DSA is equivalent to a CRDSA using a single iteration [**?**]. Trivially, SA is for $k = n = 1$.

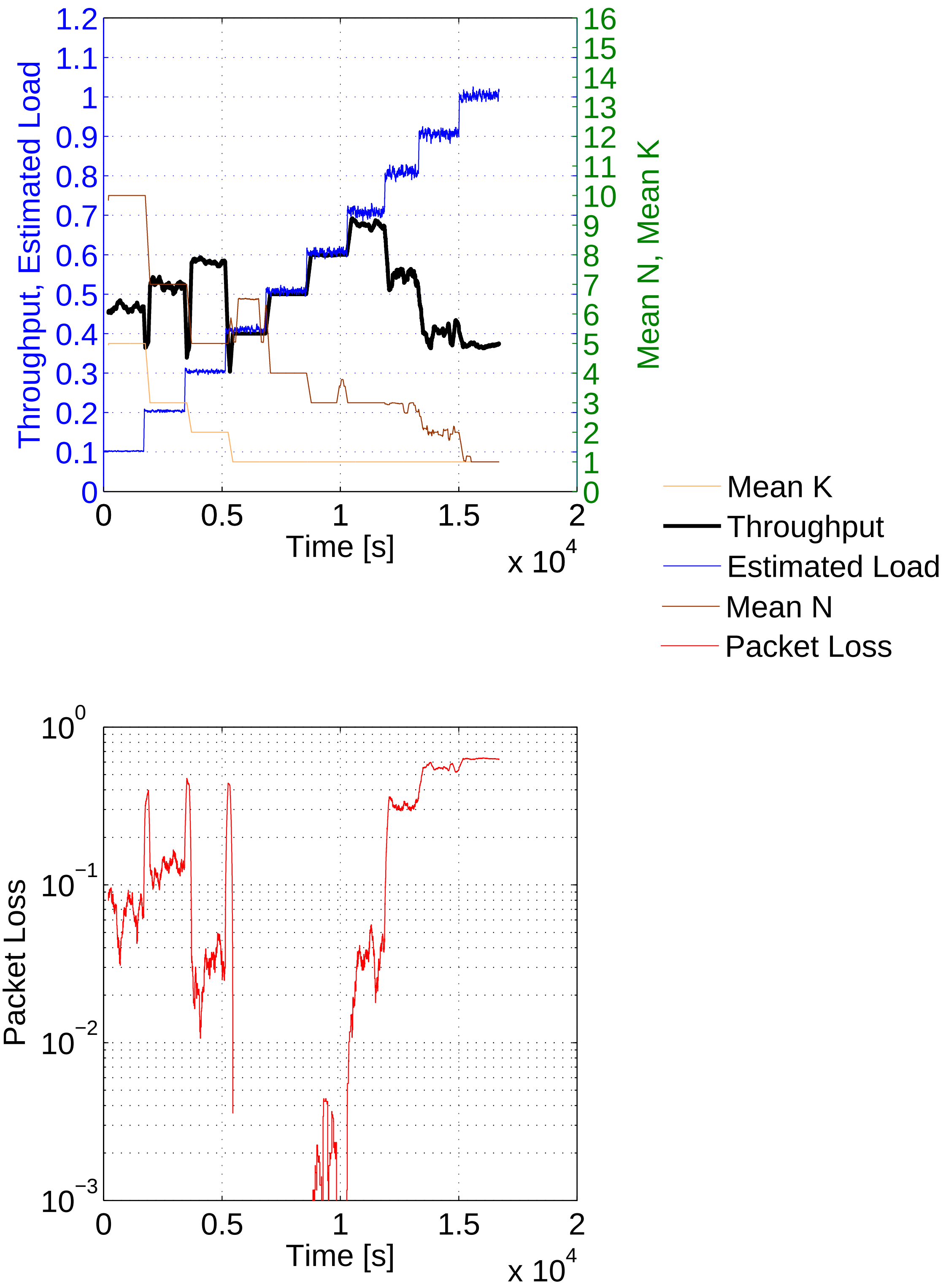

Figure 3. Throughput and Packet Loss for CE algorithm, linear code set C as in table **??**.

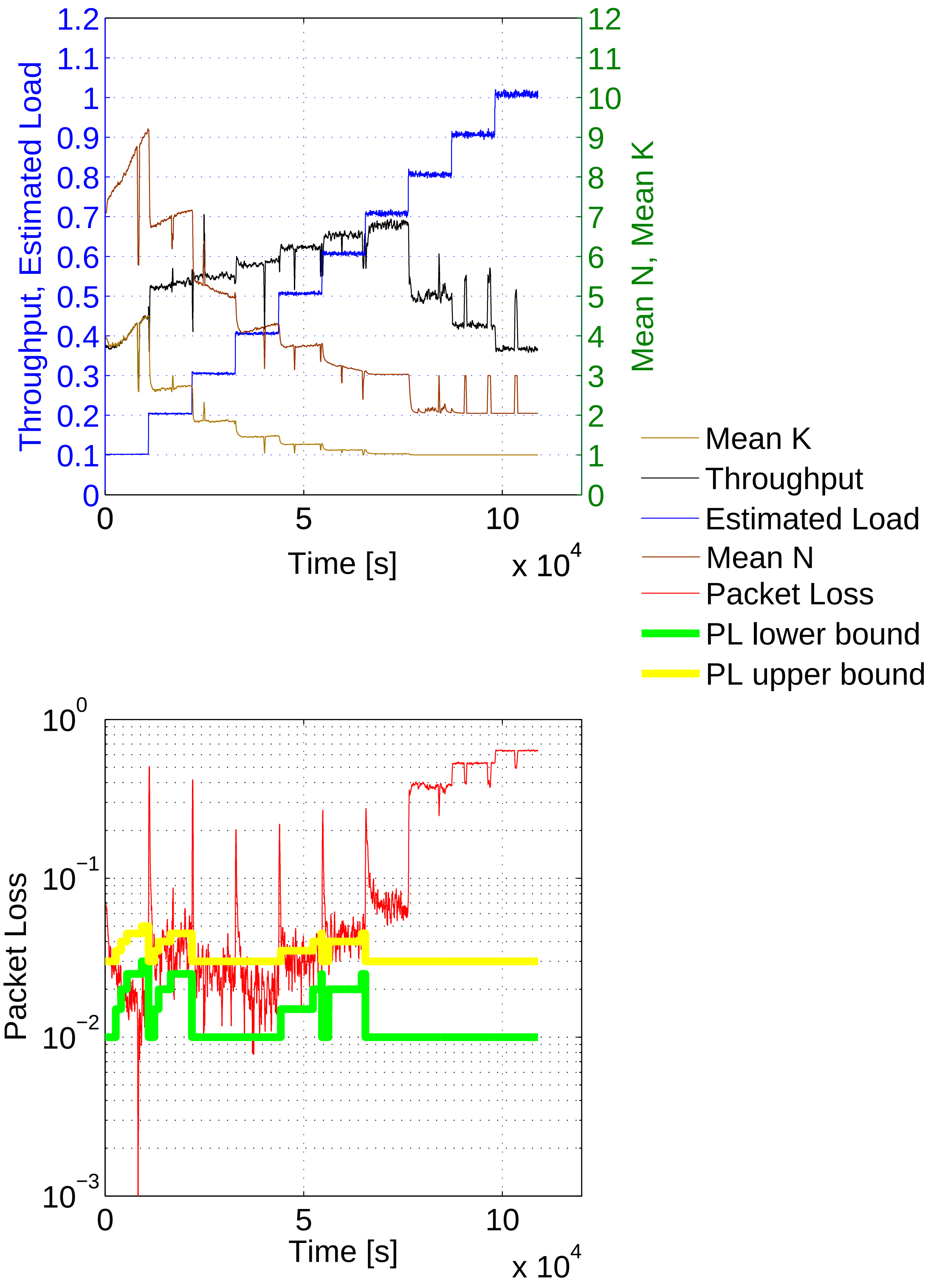

Figure 4. Throughput and Packet Loss for LC algorithm, linear code set C as in table **??**.

Figure 5. Throughput and Packet Loss for CE algorithm, linear code set C as in Table **??**.

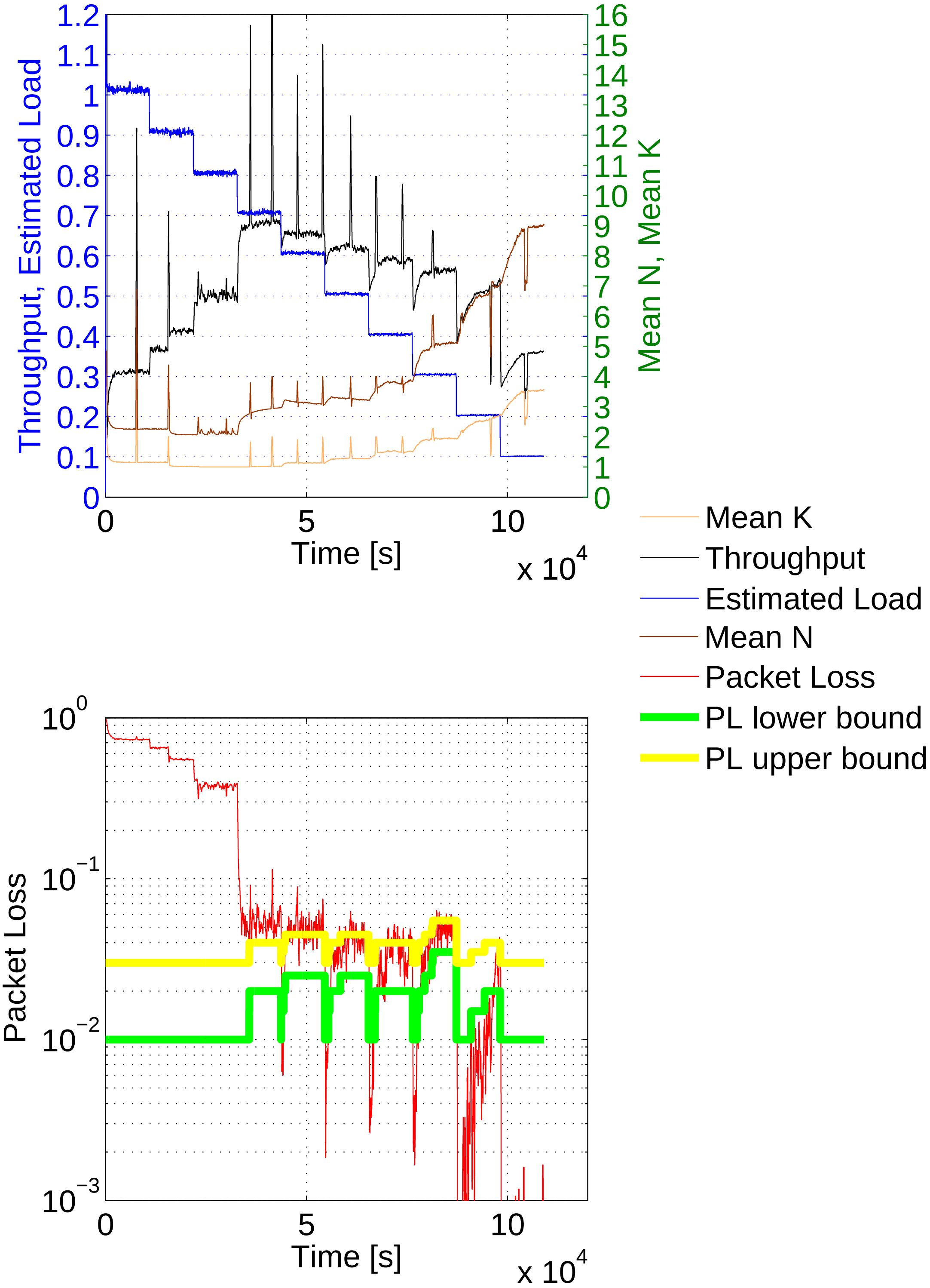

Figure 6. Throughput and Packet Loss for LC algorithm, linear code set C as in Table **??**.

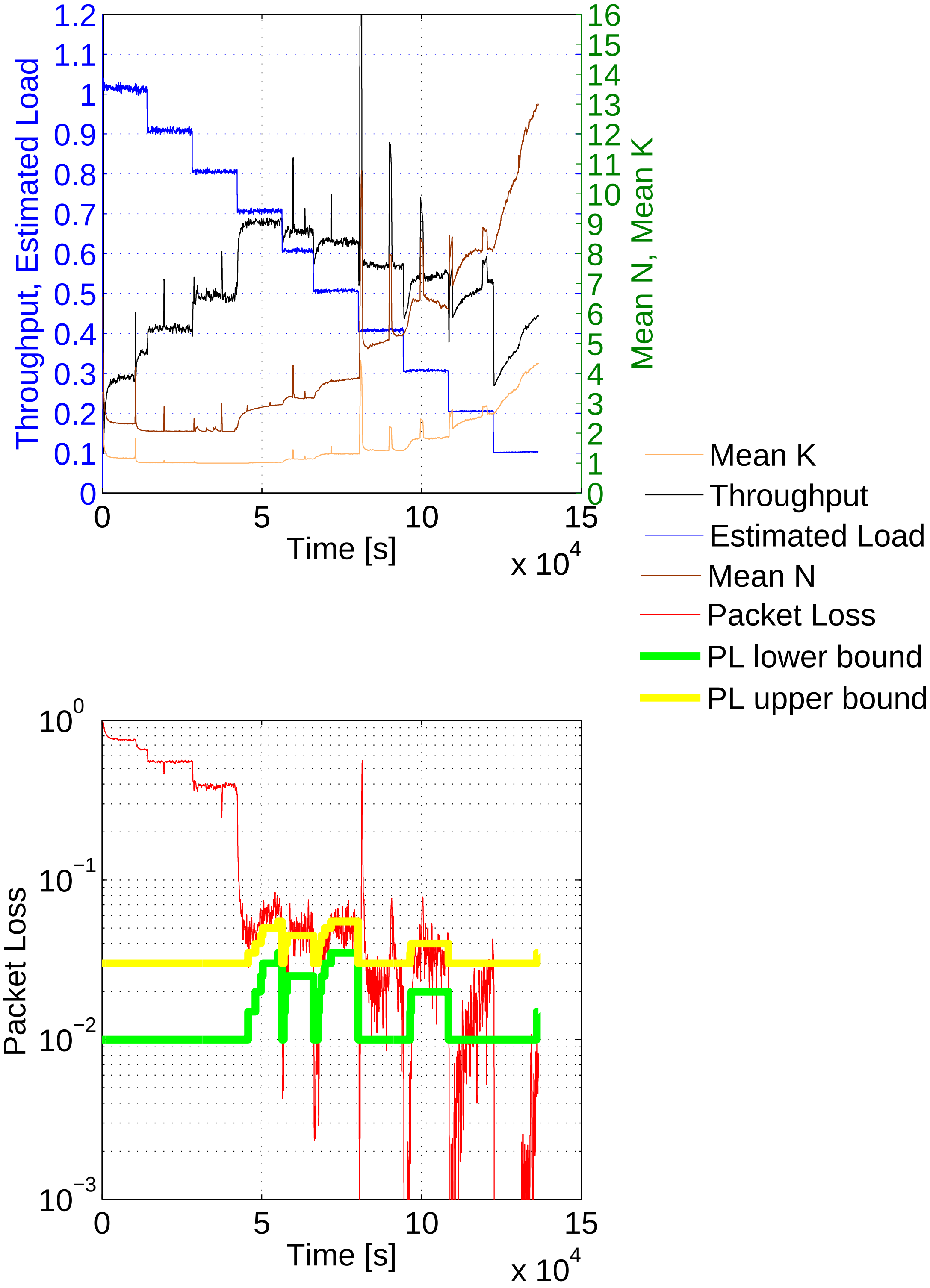

Figure 7. Throughput and Packet Loss for LC algorithm, linear code set C as in table **??**.

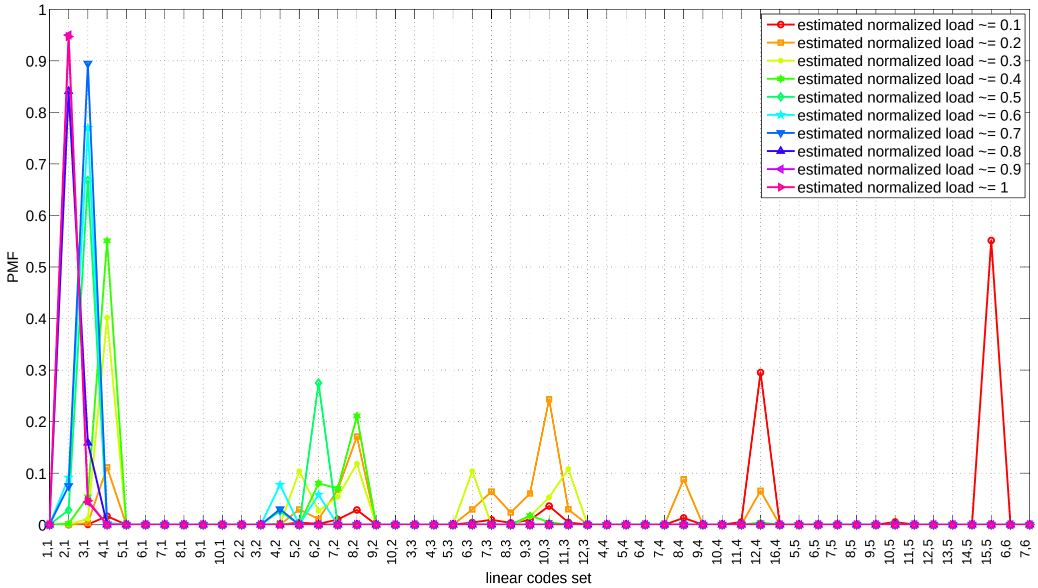

Figure 8. PMF for LC algorithm at different load levels for decreasing G, linear code set C as in table **??**.

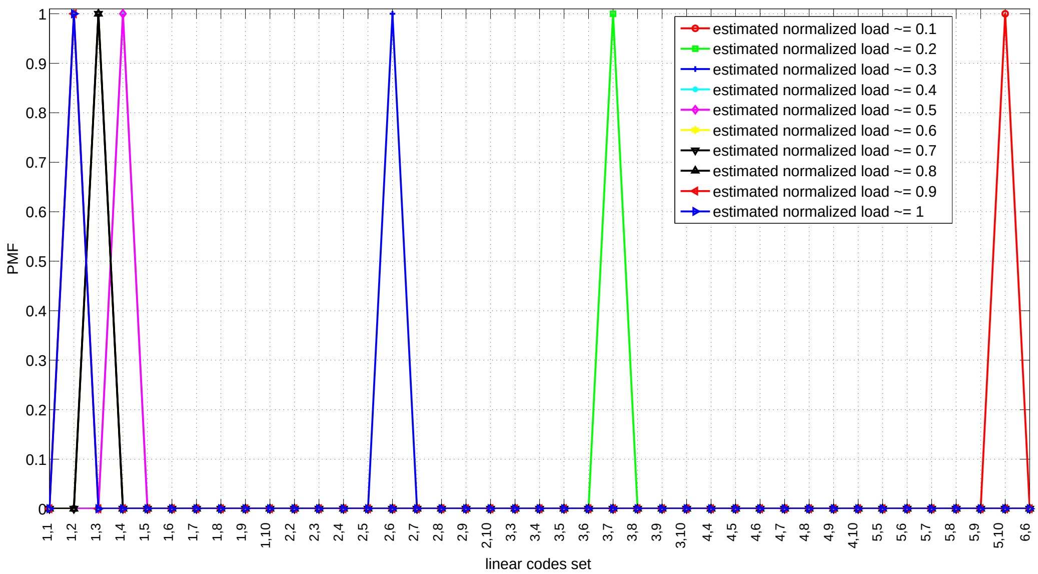

Figure 9. PMF for CE algorithm at different load levels for decreasing G, linear code set C as in table **??**.

to 0.1. The P_L bounds are shifted up in certain points, according to the algorithm described in section **??**.

Figure **??** plots the PMF of the codes that produce the highest throughput in Figure **??** (i.e., at the time instant immediately before a G variation), while Figure **??** shows the PMF of codes when the CECS is selected. Table **??** analytically describes the values of the PMF for the CECS.

Figures **??**, **??**, and **??** show the case of increasing G. In Figure **??** a throughput gain is appreciable at G from 0.4 to 0.6 with respect to Figure **??** paired with both the different choices for $(\overline{n}, \overline{k})$ and P_L with the relative

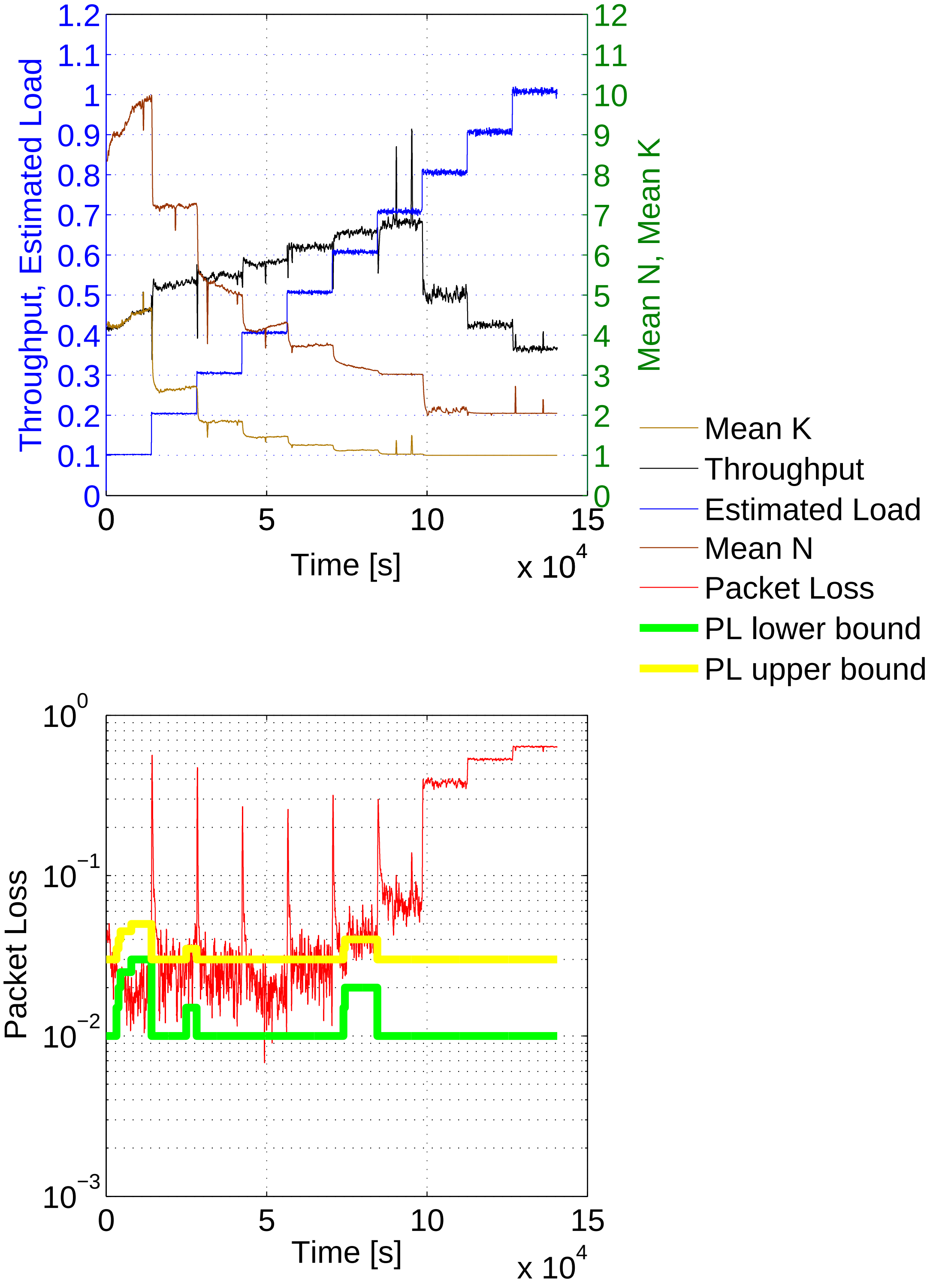

Figure 10. Throughput and Packet Loss for LC algorithm, linear code set C as in table ??.

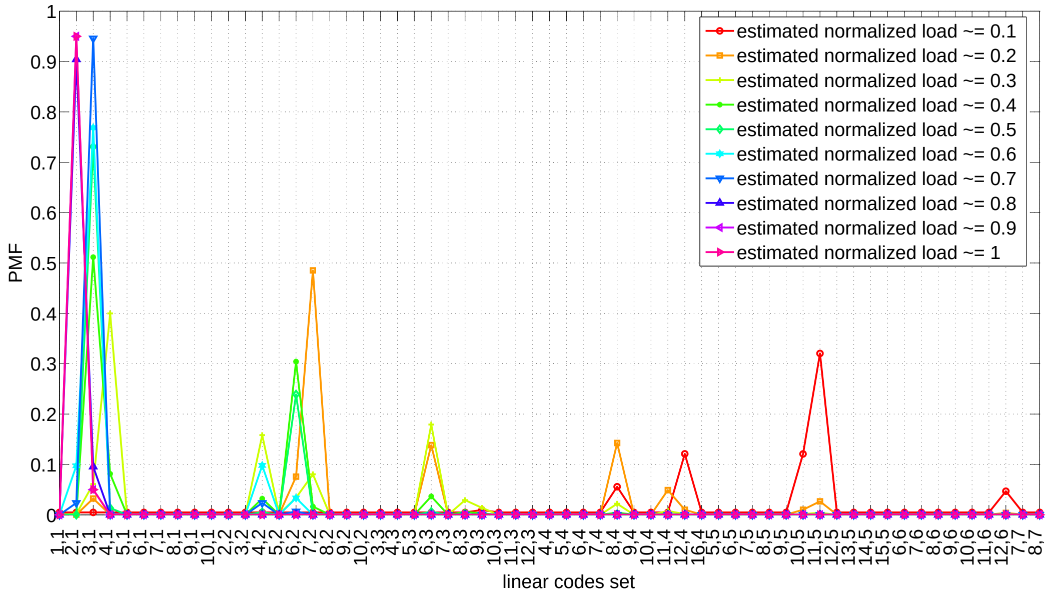

Figure 11. PMF for LC algorithm at different load levels for increasing G, linear code set C as in table **??**.

bounds. The PMF of linear codes of Figure **??** is shown in Figure **??**.

By comparing Figures **??** and **??**, it is noticeable how the load trend (i.e., increasing or decreasing) can lead to different PMF. This is explained by considering the state of the system at the time instant immediately before a load variation, because the control algorithm must quickly react to reduce the transient performance loss. This performance loss can be dependent from a too high packet loss (increasing load) or on a sub-utilization of the available bandwidth (decreasing load). Therefore, the decisions made by the LC algorithms lead to different shapes, whilst the throughput is about the same.

5. Conclusions

Contention resolution algorithms have demonstrated to successfully reduce the collision probability in random access, renewing the application of random access for information delivery. This work shows that by increasing the mean number of information packets sent by a station in each frame, when the system load is poorly loaded, the system throughput can be significantly improved up to the twice of that obtained with a standard CRDSA. In this work, we have shown how the design of a load control mechanism can help in obtaining a reasonable level of performances at each load level, avoiding the complexity of a DAMA-like (Demand Assigned Multiple Access) approach.

Since this study only accounts for colliding packets with the same $SNIR$ (Signal-to-Noise plus Interference Ratio), further improvements in terms of optimal system load G^* and maximum achievable aggregated throughput can be obtained, by considering power unbalancing and capture effect. However, achieving higher loads thanks to capture effect does not impact on the rationale behind the proposed scheme and further improvements could be shown in terms of aggregated throughput. GE-CRDSA does not neglect a load control system in order to track the optimal load correspondent to the maximum achievable throughput, but it relaxes the tracking constraints over a wider range of target loads, reducing the dynamic allocation of the collision set, i.e., the pool of slots dedicated to random access.

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