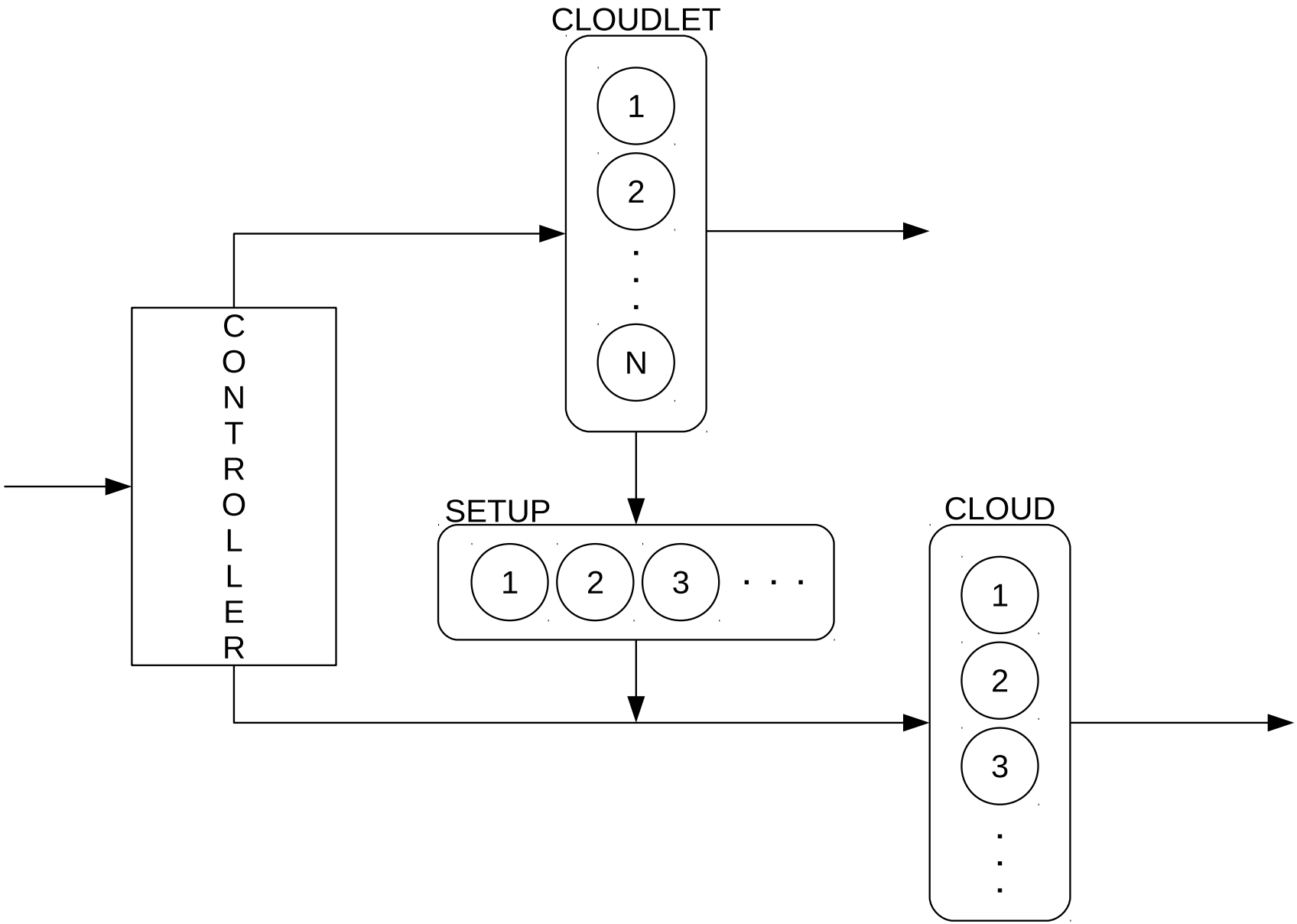
Performance Modeling Of Computer Systems And Networks

Relazione Progetto 2017/18

Simone Falvo
smvfal@gmail.com

Scaletta

Modello Concettuale



Modello di Specifica: Variabili dello stato

$n_1^{clet}(t)$	numero di job di classe 1 nel cloudlet al tempo t
$n_2^{clet}(t)$	numero di job di classe 2 nel cloudlet al tempo t
$n_1^{cloud}(t)$	numero di job di classe 1 nel cloud al tempo t
$n_2^{cloud}(t)$	numero di job di classe 2 nel cloud al tempo t
$n_{setup}(t)$	numero di job in fase di setup al tempo t

Modello di Specifica: Variabili

$s_{1,i}^{clet}$	tempo di servizio dell'i-esimo job di classe 1 eseguito nel cloudlet
$s_{2,i}^{clet}$	tempo di servizio dell'i-esimo job di classe 2 eseguito nel cloudlet
$s_{1,i}^{cloud}$	tempo di servizio dell'i-esimo job di classe 1 eseguito nel cloud
$s_{2}^{cloud,i}$	tempo di servizio dell'i-esimo job di classe 2 eseguito nel cloud
$s_{intr,i}^{clet}$	tempo di servizio nel cloudlet dell'i-esimo job interrotto
$s_{intr,i}^{cloud}$	tempo di servizio nel cloud dell'i-esimo job interrotto
s_{i}^{setup}	tempo di setup dell'i-esimo job interrotto
$c_1^{clet}(t)$	numero di job di classe 1 completati nel cloudlet al tempo t
$c_2^{clet}(t)$	numero di job di classe 2 completati nel cloudlet al tempo t
$c_1^{cloud}(t)$	numero di job di classe 1 completati nel cloud al tempo t
$c_2^{cloud}(t)$	numero di job di classe 2 completati nel cloud al tempo t
$n_{intr}(t)$	numero di job interrotti al tempo t

Modello di Specifica: Tempi di risposta

$$s_j^{clet} = \sum_{i=1}^{c_j^{clet}(t_{stop})} s_{j,i}^{clet} \qquad j = 1, 2$$

$$s_j^{cloud} = \sum_{i=1}^{c_j^{cloud}(t_{stop})} s_{j,i}^{cloud} \qquad j = 1, 2$$

$$s_{intr} = \sum_{i=1}^{n_{intr}(t_{stop})} (s_{intr,i}^{clet} + s_{intr,i}^{cloud} + s_i^{setup})$$

Modello di Specifica: Tempi di risposta

$$E[T_j^{clet}] = E[S_j^{clet}] = \frac{s_j^{clet}}{c_j^{clet}(t_{stop})} \qquad j = 1, 2$$

$$E[T_j^{cloud}] = E[S_j^{cloud}] = \frac{s_j^{cloud}}{c_j^{cloud}(t_{stop})} \qquad j = 1, 2$$

$$E[T_{intr}] = E[S_{intr}] = \frac{s_{intr}}{n_{intr}(t_{stop})}$$

Modello di Specifica: Tempi di risposta

$$E[T_1] = E[S_1] = \frac{s_1^{clet} + s_1^{cloud}}{c_1^{clet}(t_{stop}) + c_1^{cloud}(t_{stop})}$$

$$E[T_2] = E[S_2] = \frac{s_1^{clet} + s_1^{cloud} + s_{intr}}{c_2^{clet}(t_{stop}) + c_2^{cloud}(t_{stop})}$$

$$E[T] = E[S] = \frac{s_1^{clet} + s_1^{cloud} + s_2^{clet} + s_2^{cloud} + s_{intr}}{c_1^{clet}(t_{stop}) + c_1^{cloud}(t_{stop}) + c_2^{clet}(t_{stop}) + c_2^{cloud}(t_{stop})}$$

Modello di Specifica: Popolazione media

$$E[N_j^{clet}] = \frac{1}{t_{stop} - t_{start}} \int_{t_{start}}^{t_{stop}} n_j^{clet}(t)\ dt \qquad j = 1, 2$$

$$E[N_j^{cloud}] = \frac{1}{t_{stop} - t_{start}} \int_{t_{start}}^{t_{stop}} n_j^{cloud}(t)\ dt \qquad j = 1, 2$$

$$E[N_{setup}] = \frac{1}{t_{stop} - t_{start}} \int_{t_{start}}^{t_{stop}} n_{setup}(t)\ dt$$

Modello di Specifica: Popolazione media

$$E[N_1] = E[N_1^{clet}] + E[N_1^{cloud}]$$

$$E[N_2] = E[N_2^{clet}] + E[N_2^{cloud}] + E[N_{setup}]$$

$$E[N_{clet}] = E[N_1^{clet}] + E[N_2^{clet}]$$

$$E[N_{cloud}] = E[N_1^{cloud}] + E[N_2^{cloud}]$$

$$\begin{aligned} E[N] &= E[N_{cloud}] + E[N_{clet}] + E[N_{setup}] \\ &= E[N_1] + E[N_2] \end{aligned}$$

Modello di Specifica: Throughput

$$X_j^{clet} = \frac{c_j^{clet}(t_{stop})}{t_{stop} - t_{start}} \qquad j = 1, 2$$

$$X_j^{cloud} = \frac{c_j^{cloud}(t_{stop})}{t_{stop} - t_{start}} \qquad j = 1, 2$$

$$X_j = X_j^{clet} + X_j^{cloud} \qquad j = 1, 2$$

$$X_{clet} = X_1^{clet} + X_2^{clet}$$

$$X_{cloud} = X_1^{cloud} + X_2^{cloud}$$

$$X = X_1 + X_2 = X_{clet} + X_{cloud}$$

Modello di specifica: Interruzioni

$$P_{intr} = \frac{n_{intr}(t_{stop})}{c_2^{clet}(t_{stop}) + c_2^{cloud}(t_{stop})}$$

$$P_{intr}^{clet} = \frac{n_{intr}(t_{stop})}{n_{intr}(t_{stop}) + c_2^{clet}(t_{stop})}$$

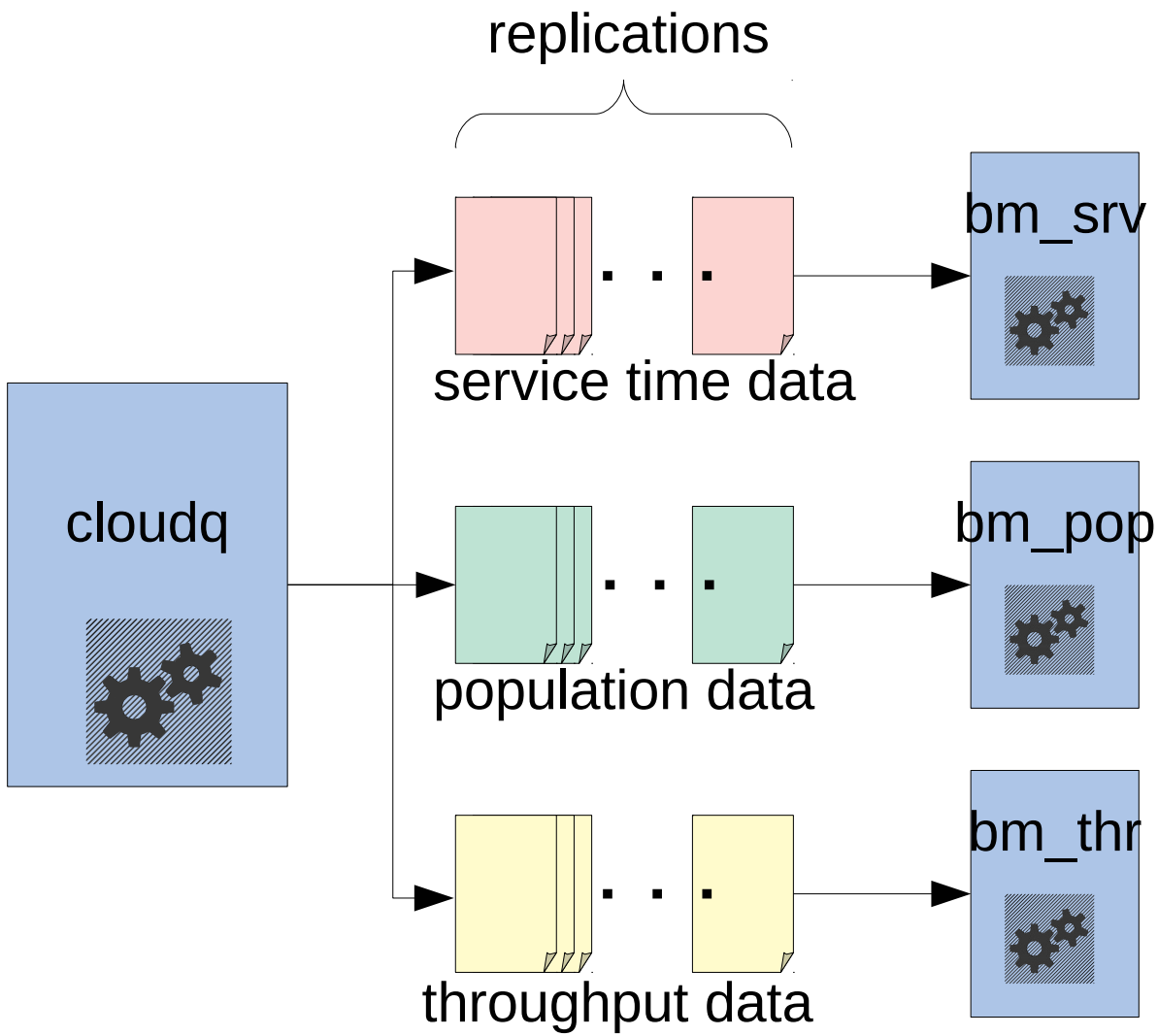
Modello di Specifica: Eventi

Arrivo di un job i di classe 1:
if $n_1^{clet}(t) = N$ **then**
  esecuzione su cloud
  $s_1^{cloud} \leftarrow s_1^{cloud} + s_{1,i}^{cloud}$
  $n_1^{cloud}(t') \leftarrow n_1^{cloud}(t) + 1$
else if $n_1^{clet}(t) + n_2^{clet}(t) < S$ **then**
  esecuzione su cloudlet
  $s_1^{clet} \leftarrow s_1^{clet} + s_{1,i}^{clet}$
  $n_1^{clet}(t') \leftarrow n_1^{clet}(t) + 1$
else if $n_2^{clet}(t) > 0$ **then**
  interruzione e setup job k di classe 2
  esecuzione su cloudlet job i di classe 1
  $s_1^{clet} \leftarrow s_1^{clet} + s_{1,i}^{clet}$
  $s_2^{clet} \leftarrow s_2^{clet} - s_2^{clet,k}$
  $s_{intr} \leftarrow s_{intr} + s_{intr,k}$
  $s_{setup} \leftarrow s_{setup} + s_{setup,k}$
  $n_{setup}(t') \leftarrow n_{setup}(t) + 1$
  $n_1^{clet}(t') \leftarrow n_1^{clet}(t) + 1$
  $n_2^{clet}(t') \leftarrow n_2^{clet}(t) - 1$
else
  esecuzione su cloudlet
  $s_1^{clet} \leftarrow s_1^{clet} + s_{1,i}^{clet}$
  $n_1^{clet}(t') \leftarrow n_1^{clet}(t) + 1$
end if

Modello di Specifica: Eventi

Arrivo di un job i di classe 2:
if $n_1^{clet}(t) + n_2^{clet}(t) \geq S$ **then**
esecuzione su cloud
$s_2^{cloud} \leftarrow s_2^{cloud} + s_2^{cloud,i}$
$n_2^{cloud}(t') \leftarrow n_2^{cloud}(t) + 1$
else
esecuzione su cloudlet
$s_2^{clet} \leftarrow s_2^{clet} + s_{2,i}^{clet}$
$n_2^{clet}(t') \leftarrow n_2^{clet}(t) + 1$
end if
Partenza di un job di classe j dal cloudlet:
$c_j^{clet}(t') \leftarrow c_j^{clet}(t) + 1$
$n_j^{clet}(t') \leftarrow n_j^{clet}(t) - 1$
Partenza di un job di classe j dal cloud:
$c_j^{cloud}(t') \leftarrow c_j^{cloud}(t) + 1$
$n_j^{cloud}(t') \leftarrow n_j^{cloud}(t) - 1$
Setup:
esecuzione su cloud
$s_2^{cloud} \leftarrow s_2^{cloud} + s_2^{cloud,i}$
$n_{setup}(t') \leftarrow n_{setup}(t) - 1$
$n_2^{cloud}(t') \leftarrow n_2^{cloud}(t) + 1$

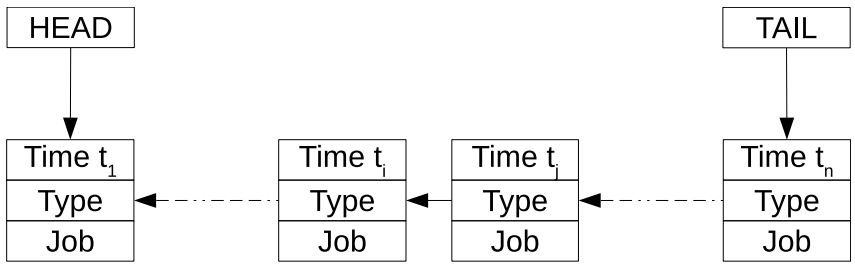
Modello Computazionale



Modello Computazionale: Next Event Simulation

```
typedef struct {
    double current;
    double next;
} clock;

struct job_t {
    unsigned long id;
    unsigned int class;
    unsigned int node;
    double service[5];
};

struct event {
    double time;
    struct job_t job;
    unsigned int type;
};
```

- prossimo arrivo di un job
- al più N completamenti di job nel cloudlet
- 0 o più completamenti di job nel cloud
- 0 o più completamenti di fase di setup dei job interrotti



$t_i < t_j \; \forall \, i < j$

Modello Computazionale: Flusso principale

```
/* initialize data structures */
/* ..... */

while (queue.head != NULL) {

    e = dequeue_event(&queue);
    t.next = e->time;

    for (i = 0; i < 5; i++)
        area[i] += (t.next - t.current) * n[i

    t.current = t.next;

    switch (e->type) {
    case E_ARRIVL:
        /* process an arrival */
        /* ..... */
    case E_SETUP:
        /* process an setup phase */
        /* ..... */
    case E_DEPART:
        /* process a departure */
        /* ..... */
        /* write data to outfile */
        /* ..... */
    default:
        handle_error("unknown event type");
    }
}

/* ..... */
```

```
-1 195534 117496 79 186891 72968
0 1.416729 0.000000 0.000000 0.000000 0.000000
1 0.000000 3.156181 0.000000 9.557601 2.238222
2 0.000000 1.377074 0.000000 0.000000 0.000000
3 0.000000 4.429047 0.000000 8.041242 1.146876
4 0.000000 7.618982 0.000000 0.156040 1.184683
5 0.000000 1.205712 0.000000 0.000000 0.000000
6 0.174604 0.000000 0.000000 0.000000 0.000000
7 0.000000 4.121710 0.000000 0.341923 0.913647
8 0.000000 2.224049 0.000000 12.047245 1.172166
9 1.834970 0.000000 0.000000 0.000000 0.000000
10 0.000000 2.160139 0.000000 0.000000 0.000000
11 0.000000 2.597631 0.000000 0.000000 0.000000
12 0.000000 3.464442 0.000000 4.141120 0.686988
13 1.700777 0.000000 0.000000 0.000000 0.000000
14 0.000000 1.602881 0.000000 9.238383 0.855053
15 2.839319 0.000000 0.000000 0.000000 0.000000
16 0.000000 2.736957 0.000000 6.867536 0.652533
17 0.000000 1.461287 0.000000 4.197081 0.301347
18 0.000000 1.364863 0.000000 5.189565 2.463572
19 0.000000 0.137472 0.000000 0.000000 0.000000
20 4.589725 0.000000 0.000000 0.000000 0.000000
```

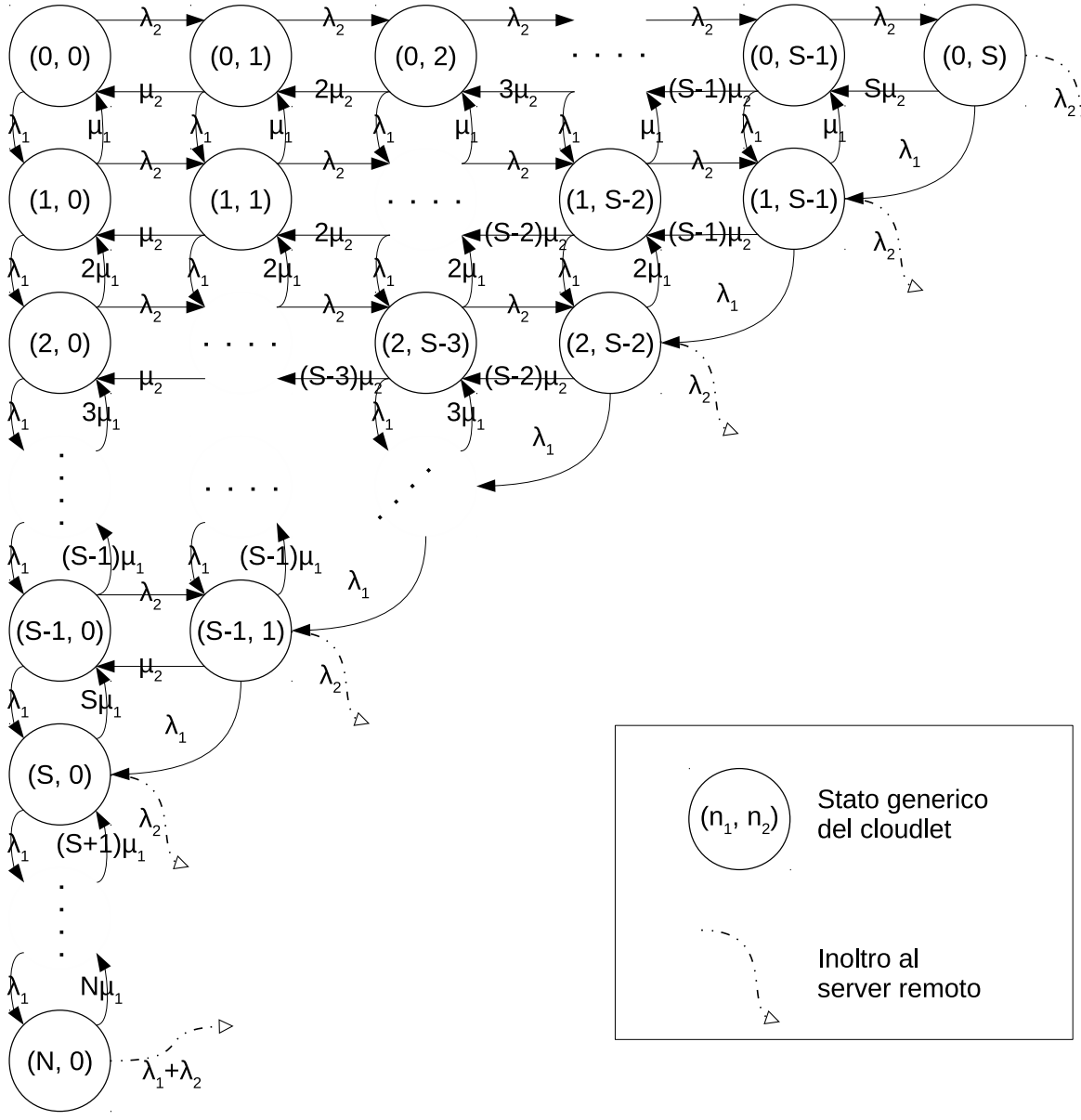
Modello Computazionale: Batch Means

```
// compute batch sizes
b = (c1_clet + c2_clet + c1_cloud + c2_cloud) / K;
b1 = (c1_clet + c1_cloud) / K;
b2 = (c2_clet + c2_cloud) / K;
b_clet = (c1_clet + c2_clet) / K;
b1_clet = c1_clet / K;
b2_clet = c2_clet / K;
b_cloud = (c1_cloud + c2_cloud) / K;
b1_cloud = c1_cloud / K;
b2_cloud = c2_cloud / K;
b_intr = c_setup / K;

// get data
while (fscanf(file, "%ld %lf %lf %lf %lf %lf\n", &id,
        &s1_clet, &s2_clet, &s1_cloud, &s2_cloud, &setup) != EOF) {

    s[id / b] += s1_clet + s2_clet + s1_cloud + s2_cloud + setup;

    if (s1_clet || s1_cloud) {
        s1[n1 / b1] += s1_clet + s1_cloud;
        n1++;
    }
    if (s2_clet || s2_cloud) {
        s2[n2 / b2] += s2_clet + s2_cloud + setup;
        n2++;
    }
    if (s1_clet) {
        s1clet[n1_clet / b1_clet] += s1_clet;
        sclet[(n1_clet + n2_clet) / b_clet] += s1_clet;
        n1_clet++;
    }
```

Modello Computazionale: Batch Means

```
    if (s2_clet && !setup) {
        s2clet[n2_clet / b2_clet] += s2_clet;
        sclet[(n1_clet + n2_clet) / b_clet] += s2_clet;
        n2_clet++;
    }
    if (s1_cloud) {
        s1cloud[n1_cloud / b1_cloud] += s1_cloud;
        scloud[(n1_cloud + n2_cloud) / b_cloud] += s1_cloud;
        n1_cloud++;
    }
    if (s2_cloud) {
        s2cloud[n2_cloud / b2_cloud] += s2_cloud;
        scloud[(n1_cloud + n2_cloud) / b_cloud] += s2_cloud;
        n2_cloud++;
    }
    if (setup) {
        sintr[n_intr / b_intr] += s2_clet + s2_cloud + setup;
        n_intr++;
    }
}
// compute batch means
for (i = 0; i < K; i++) {
    s[i] /= b;
    s1[i] /= b1;
    s2[i] /= b2;
    s1clet[i] /= b1_clet;
    s2clet[i] /= b2_clet;
    sclet[i] /= b_clet;
    s1cloud[i] /= b1_cloud;
    s2cloud[i] /= b2_cloud;
    scloud[i] /= b_cloud;
    sintr[i] /= b_intr;
}
```

Modello Analitico: Catena di Markov



Modello Analitico: Probabilità Preliminari

- *Probabilità di Accettazione*

$$\Pi_A = \sum_{\substack{n_1,n_2: \\ n_1+n_2<S}} \pi_{(n_1,n_2)}$$

- *Probabilità di Soglia*

$$\Pi_S = \sum_{\substack{n_1,n_2: \\ n_1+n_2\geq S}} \pi_{(n_1,n_2)}$$

- *Probabilità di Blocco*

$$\Pi_B = \sum_{\substack{n_1,n_2: \\ n_1+n_2=N}} \pi_{(n_1,n_2)}$$

- *Probabilità di Interruzione*

$$\Pi_I = \sum_{\substack{n_1,n_2: \\ n_1+n_2=N \\ n_2>0}} \pi_{(n_1,n_2)}$$

- *Probabilità di Interruzione a seguito di Accettazione*

$$P_{intr}^{clet} = \frac{\lambda_1 \, \Pi_I}{\lambda_2 \, \Pi_A}$$

- *Probabilità di Interruzione di un job di classe 2*

$$P_{intr} = \Pi_A \; P_{intr}^{clet}$$

Modello Analitico: Throughput

$$\lambda_1^{cloud} = \Pi_B \ \lambda_1 \qquad\qquad \lambda_2^{cloud} = \lambda_{setup} = (\Pi_S + P_{intr}) \ \lambda_2$$

$$\begin{aligned}
X_j^{cloud} &= \lambda_j^{cloud} && j = 1, 2 \\
X_{cloud} &= \lambda_1^{cloud} + \lambda_2^{cloud} \\
X^{setup} &= \lambda_{setup} \\
X_j &= \lambda_j && j = 1, 2 \\
X &= \lambda \\
X_j^{clet} &= X_j - X_j^{cloud} && j = 1, 2 \\
X_{clet} &= X - X_{cloud}
\end{aligned}$$

Modello Analitico: Tempo di Risposta Locale

$$E[S_1^{cloud}] = \frac{1}{\mu_1^{cloud}} \qquad E[S_2^{cloud}] = \frac{1}{\mu_2^{cloud}}$$

$$E[S_{cloud}] = \frac{\lambda_1^{cloud}}{\lambda_1^{cloud} + \lambda_2^{cloud}} E[S_1^{cloud}] + \frac{\lambda_2^{cloud}}{\lambda_1^{cloud} + \lambda_2^{cloud}} E[S_2^{cloud}]$$

$$E[S_1^{clet}] = \frac{1}{\mu_1^{clet}}$$

$$E[S_2^{clet}] = \frac{1}{\mu_2^{clet}} - E[S_r] = \frac{1}{\mu_2^{clet}} - \frac{1}{\mu_2^{clet}} P_{intr}^{clet} = \frac{1}{\mu_2^{clet}}(1 - P_{intr}^{clet})$$

$$E[S_{clet}] = \frac{X_1^{clet}}{X_1^{clet} + X_2^{clet}} E[S_1^{clet}] + \frac{X_2^{clet}}{X_1^{clet} + X_2^{clet}} E[S_2^{clet}]$$

Modello Analitico: Tempo di Risposta Globale

$$E[S_1] = (1 - \Pi_B)\ E[S_1^{clet}]\ +\ \Pi_B\ E[S_1^{cloud}]$$

$$E[S_{intr}] = (1 - \beta P_{intr}^{clet})\frac{1}{\mu_2^{clet}} + E[S_{setup}] + E[S_{cloud}] \qquad \beta = 0.95$$

$$E[S_2] = \Pi_S E[S_2^{cloud}] + \Pi_A(1 - P_{intr}^{clet})E[S_2^{clet}] + P_{intr}E[S_{intr}]$$

$$E[S] = \frac{\lambda_1}{\lambda_1 + \lambda_2}E[S_1] + \frac{\lambda_2}{\lambda_1 + \lambda_2}E[S_2]$$

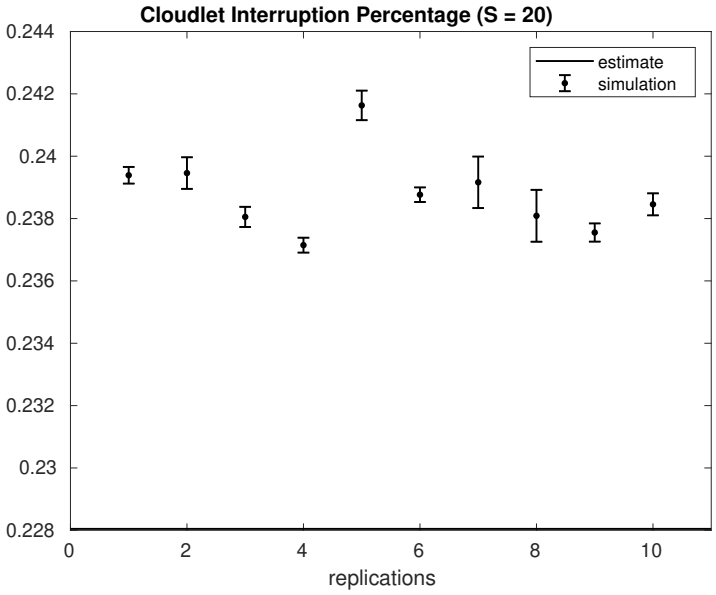
Modello Analitico: Tempo di Risposta Globale

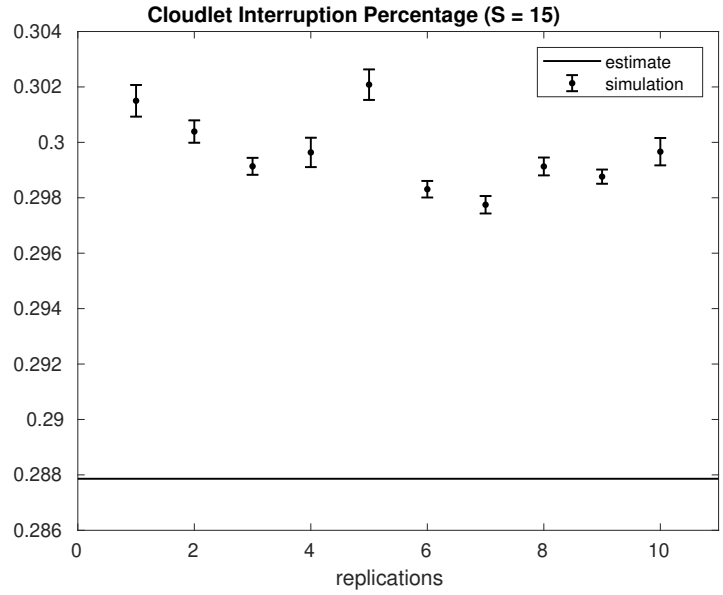
$$E[N_j^{cloud}] = \lambda_j^{cloud} E[S_j^{cloud}] \qquad j = 1, 2$$
$$E[N_{cloud}] = (\lambda_1^{cloud} + \lambda_2^{cloud}) E[S_{cloud}]$$

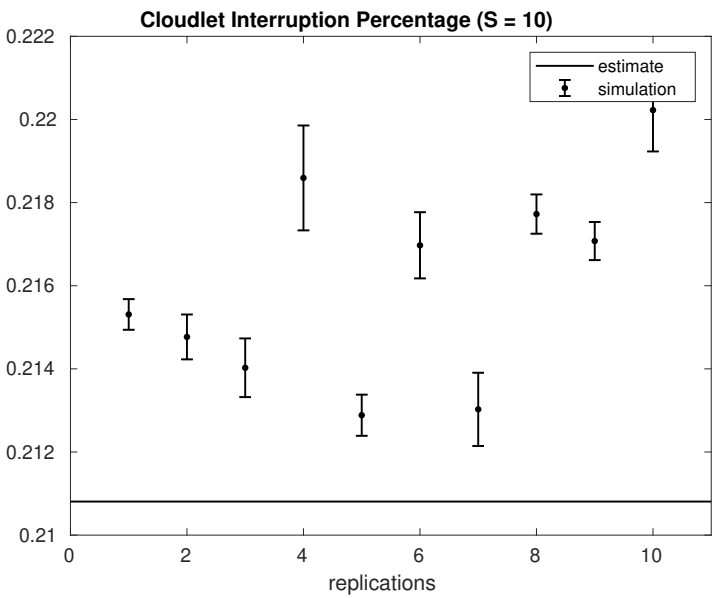
$$E[N_1^{clet}] = \sum_{(n_1,n_2) \in E} n_1 \ \pi_{(n_1,n_2)} \qquad E[N_2^{clet}] = \sum_{(n_1,n_2) \in E} n_2 \ \pi_{(n_1,n_2)}$$
$$E[N_{clet}] = \sum_{(n_1,n_2) \in E} (n_1 + n_2) \ \pi_{(n_1,n_2)}$$

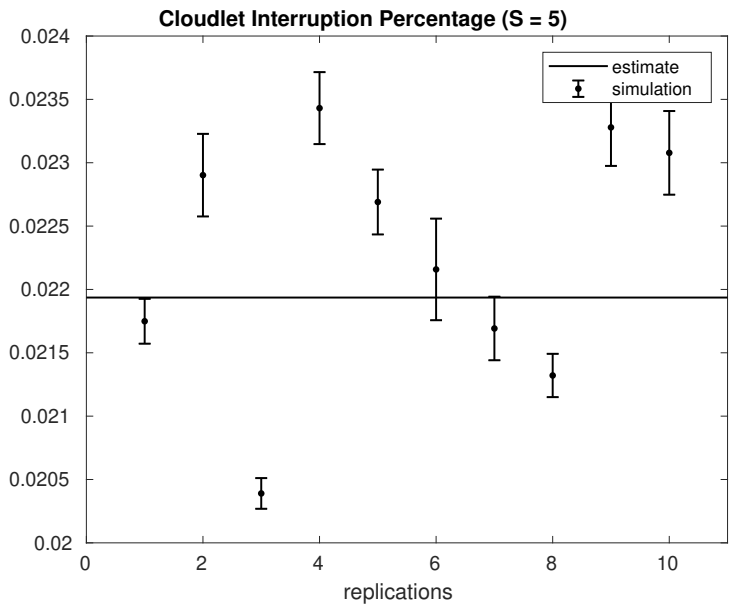
$$E[N_j] = \lambda_j E[S_j] \qquad j = 1, 2$$
$$E[N] = (\lambda_1 + \lambda_2) E[S]$$

Risultati: Percentuale Interruzioni







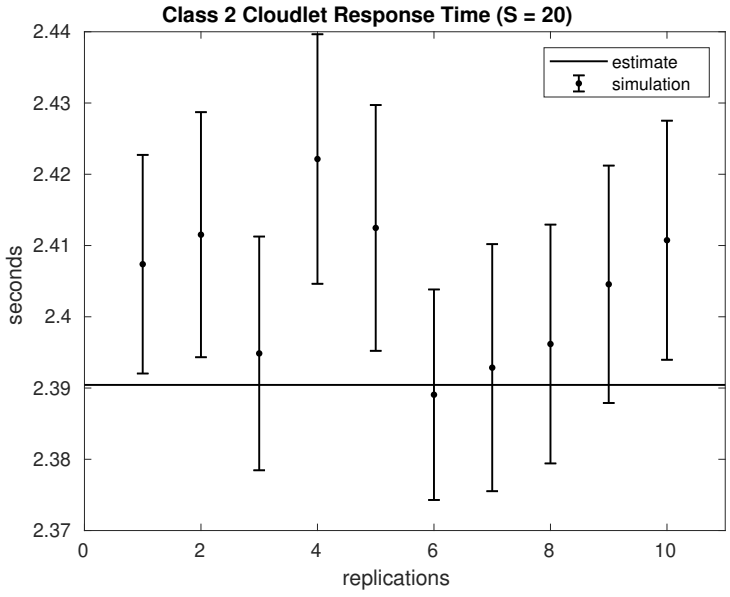


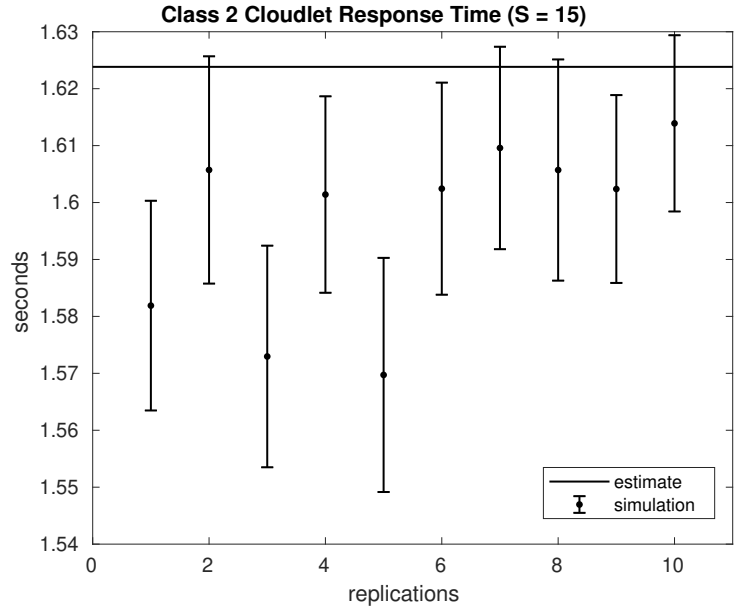
Risultati: Percentuale Interruzioni

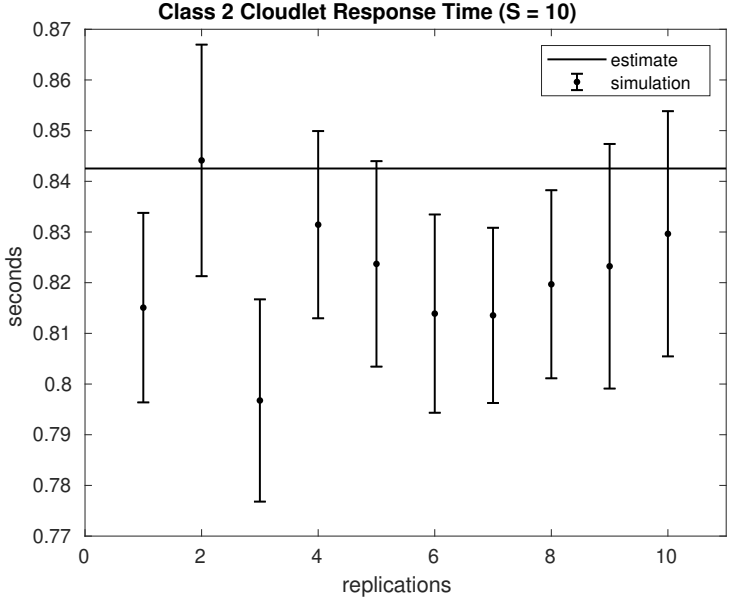
	$S = 20$	$S = 15$	$S = 10$	$S = 5$
R1	0.2394 ± 0.0003	0.3015 ± 0.0006	0.2153 ± 0.0004	0.0217 ± 0.0002
R2	0.2395 ± 0.0005	0.3004 ± 0.0004	0.2148 ± 0.0005	0.0229 ± 0.0003
R3	0.2381 ± 0.0003	0.2991 ± 0.0003	0.2140 ± 0.0007	0.0204 ± 0.0001
R4	0.2371 ± 0.0002	0.2996 ± 0.0005	0.2186 ± 0.0013	0.0234 ± 0.0003
R5	0.2416 ± 0.0005	0.3021 ± 0.0006	0.2129 ± 0.0005	0.0227 ± 0.0003
R6	0.2388 ± 0.0002	0.2983 ± 0.0003	0.2170 ± 0.0008	0.0222 ± 0.0004
R7	0.2392 ± 0.0008	0.2977 ± 0.0003	0.2130 ± 0.0009	0.0217 ± 0.0003
R8	0.2381 ± 0.0008	0.2991 ± 0.0003	0.2177 ± 0.0005	0.0213 ± 0.0002
R9	0.2376 ± 0.0003	0.2988 ± 0.0003	0.2171 ± 0.0005	0.0233 ± 0.0003
R10	0.2385 ± 0.0004	0.2997 ± 0.0005	0.2202 ± 0.0010	0.0231 ± 0.0003
EST	0.2280	0.2879	0.2108	0.0219
ε_{max}	0.0141 (5.8%)	0.0148 (4.9%)	0.0104 (4.7%)	0.0018 (7.6%)

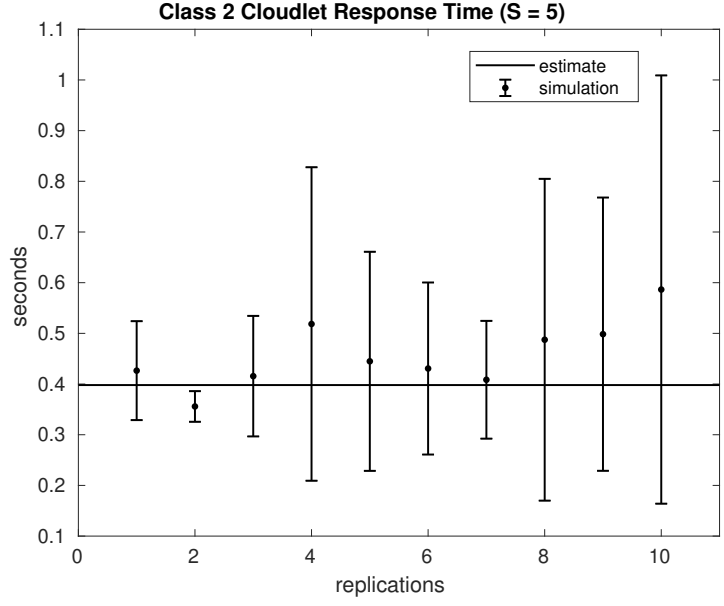
Table: percentuale job di classe 2 interrotti

Risultati: Tempo di Risposta Cloudlet Classe 2







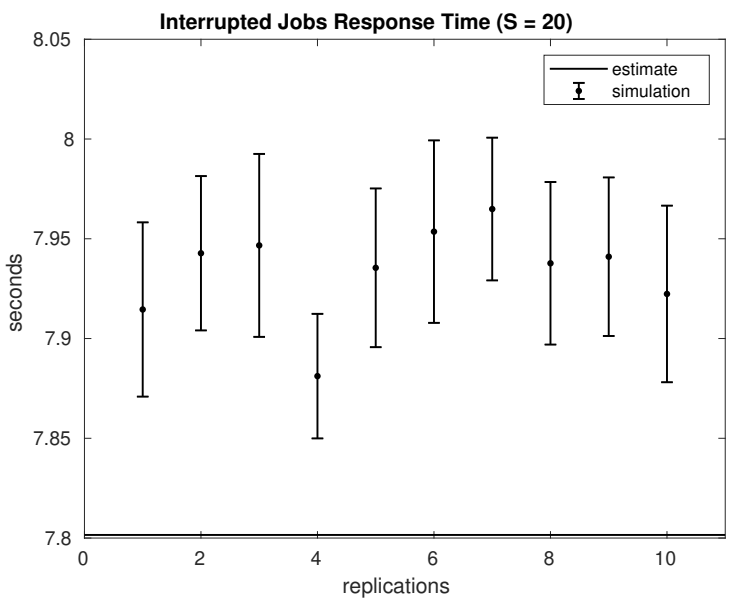


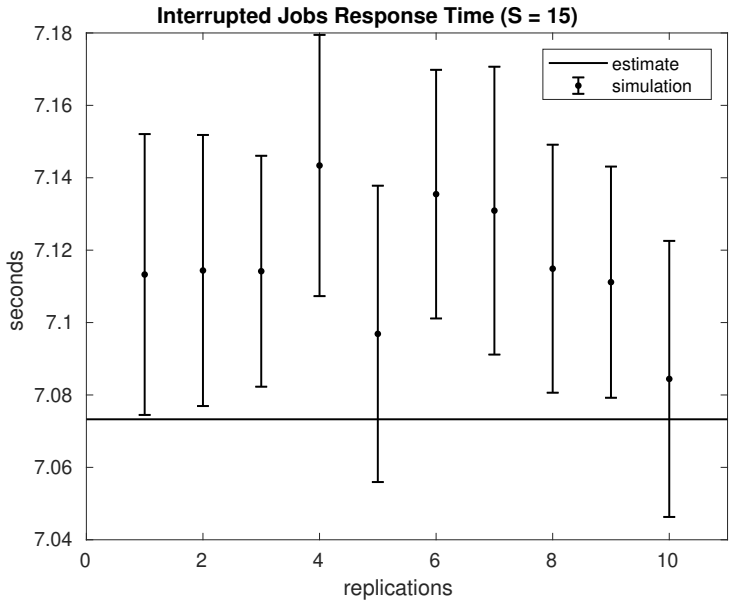
Risultati: Tempo di Risposta Cloudlet Classe 2

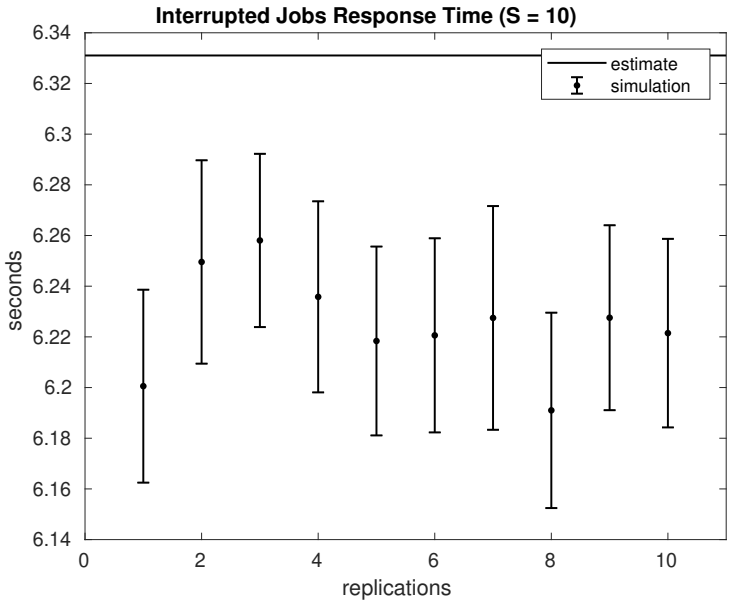
	$S = 20$	$S = 15$	$S = 10$	$S = 5$
R1	2.4074 ± 0.0153	1.5819 ± 0.0184	0.8151 ± 0.0187	0.4265 ± 0.0976
R2	2.4115 ± 0.0172	1.6057 ± 0.0200	0.8441 ± 0.0228	0.3558 ± 0.0302
R3	2.3949 ± 0.0164	1.5730 ± 0.0195	0.7968 ± 0.0199	0.4156 ± 0.1189
R4	2.4221 ± 0.0175	1.6014 ± 0.0173	0.8314 ± 0.0185	0.5185 ± 0.3093
R5	2.4125 ± 0.0172	1.5697 ± 0.0206	0.8237 ± 0.0203	0.4449 ± 0.2161
R6	2.3891 ± 0.0148	1.6024 ± 0.0186	0.8139 ± 0.0196	0.4307 ± 0.1697
R7	2.3929 ± 0.0173	1.6096 ± 0.0178	0.8136 ± 0.0173	0.4085 ± 0.1162
R8	2.3962 ± 0.0168	1.6057 ± 0.0194	0.8197 ± 0.0186	0.4874 ± 0.3175
R9	2.4046 ± 0.0167	1.6024 ± 0.0165	0.8232 ± 0.0241	0.4984 ± 0.2696
R10	2.4107 ± 0.0168	1.6139 ± 0.0155	0.8296 ± 0.0242	0.5865 ± 0.4225
EST	2.3904	1.6238	0.8425	0.3980
ε_{max}	0.0492 (2.0%)	0.0336 (2.1%)	0.0258 (3.2%)	0.6110 (104.2%)

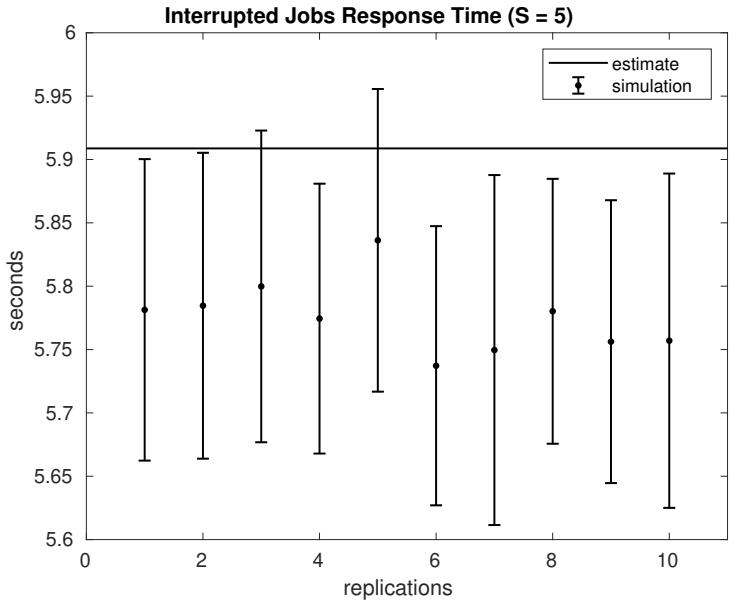
Table: tempo di risposta cloudlet classe 2

Risultati: Tempo di Risposta Job Interrotti







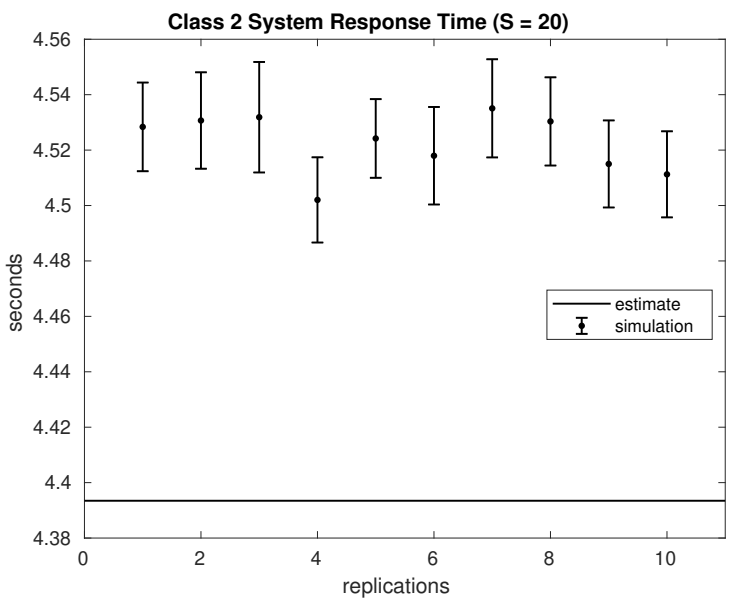


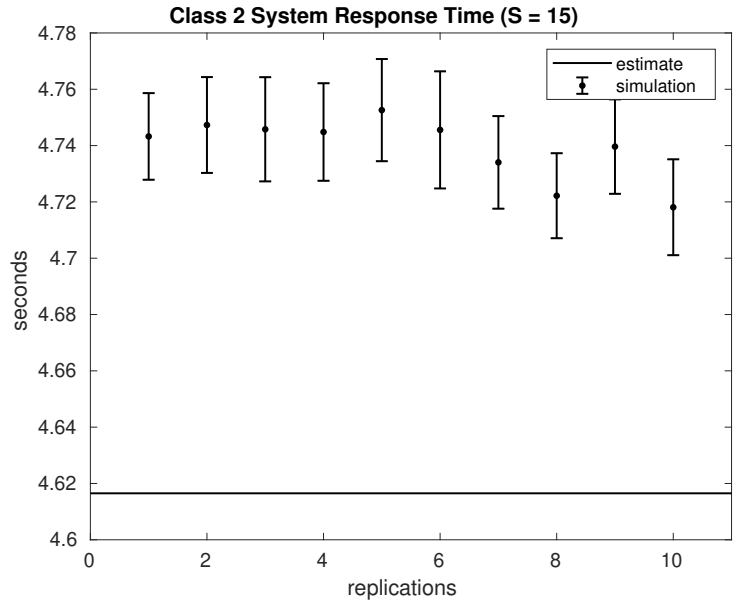
Risultati: Tempo di Risposta Job Interrotti

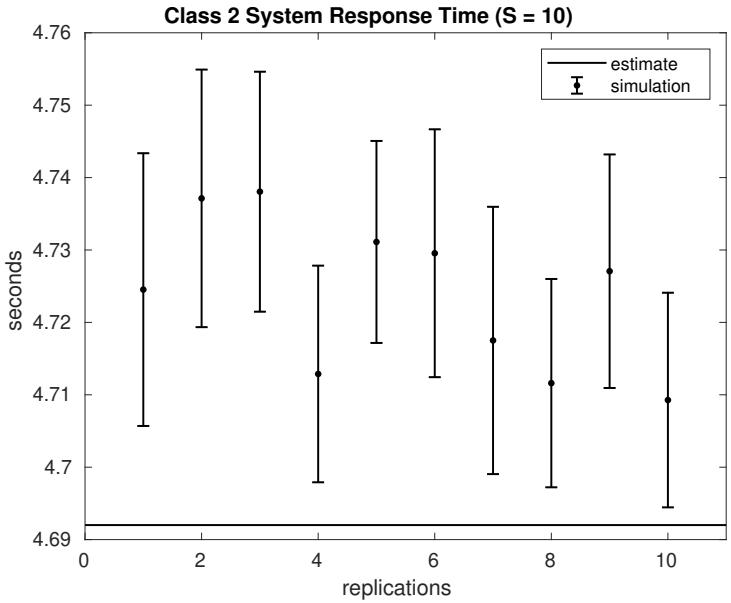
	$S = 20$	$S = 15$	$S = 10$	$S = 5$
R1	7.9146 ± 0.0437	7.1133 ± 0.0388	6.2006 ± 0.0381	5.7813 ± 0.1190
R2	7.9427 ± 0.0387	7.1144 ± 0.0374	6.2496 ± 0.0401	5.7846 ± 0.1207
R3	7.9467 ± 0.0458	7.1142 ± 0.0319	6.2580 ± 0.0342	5.7998 ± 0.1230
R4	7.8812 ± 0.0312	7.1434 ± 0.0361	6.2358 ± 0.0377	5.7744 ± 0.1065
R5	7.9354 ± 0.0398	7.0969 ± 0.0409	6.2184 ± 0.0373	5.8362 ± 0.1194
R6	7.9536 ± 0.0457	7.1355 ± 0.0343	6.2206 ± 0.0383	5.7372 ± 0.1102
R7	7.9649 ± 0.0358	7.1309 ± 0.0398	6.2275 ± 0.0441	5.7496 ± 0.1381
R8	7.9377 ± 0.0407	7.1149 ± 0.0343	6.1910 ± 0.0386	5.7802 ± 0.1045
R9	7.9410 ± 0.0397	7.1112 ± 0.0319	6.2276 ± 0.0365	5.7562 ± 0.1116
R10	7.9223 ± 0.0443	7.0844 ± 0.0381	6.2215 ± 0.0372	5.7570 ± 0.1319
EST	7.8016	7.0733	6.3310	5.9087
ε_{max}	0.1991 (2.5%)	0.1062 (1.5%)	0.1015 (1.6%)	0.0614 (1.1%)

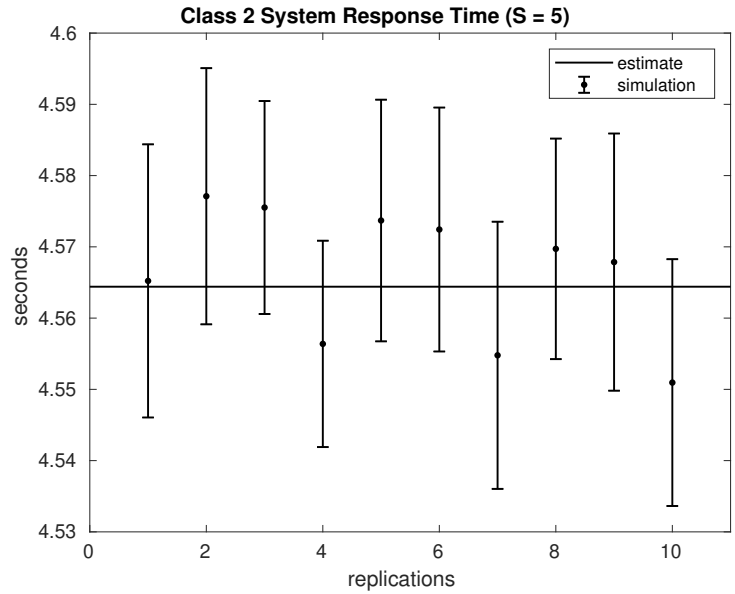
Table: tempo di risposta job interrotti

Risultati: Tempo di Risposta Sistema Classe 2







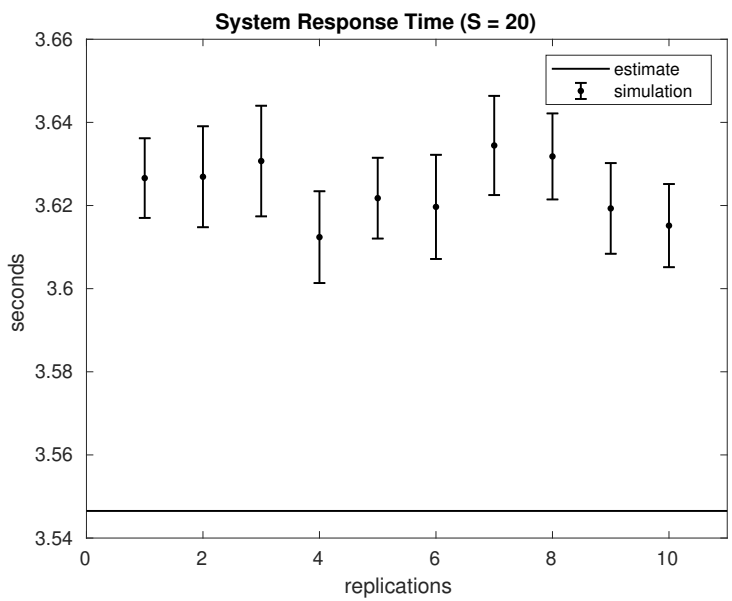


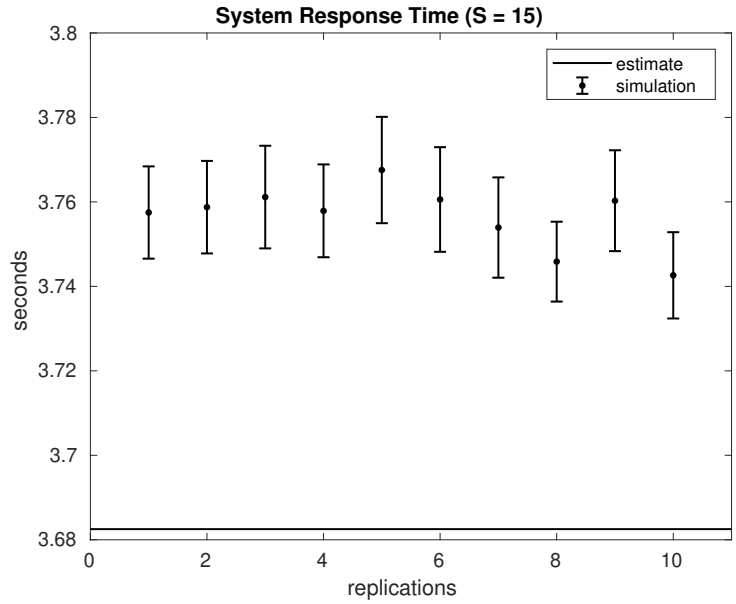
Risultati: Tempo di Risposta Sistema Classe 2

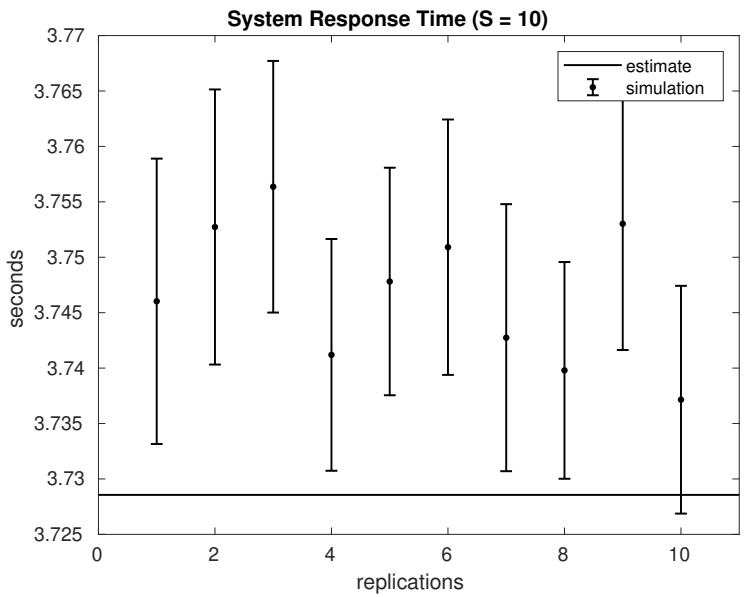
	$S = 20$	$S = 15$	$S = 10$	$S = 5$
R1	4.5284 ± 0.0160	4.7433 ± 0.0154	4.7245 ± 0.0188	4.5652 ± 0.0192
R2	4.5307 ± 0.0174	4.7473 ± 0.0170	4.7371 ± 0.0178	4.5771 ± 0.0180
R3	4.5319 ± 0.0199	4.7458 ± 0.0185	4.7381 ± 0.0166	4.5755 ± 0.0149
R4	4.5020 ± 0.0154	4.7448 ± 0.0173	4.7129 ± 0.0150	4.5564 ± 0.0145
R5	4.5242 ± 0.0142	4.7526 ± 0.0181	4.7311 ± 0.0139	4.5737 ± 0.0170
R6	4.5180 ± 0.0176	4.7456 ± 0.0208	4.7295 ± 0.0171	4.5724 ± 0.0171
R7	4.5351 ± 0.0177	4.7340 ± 0.0164	4.7175 ± 0.0185	4.5548 ± 0.0187
R8	4.5303 ± 0.0159	4.7222 ± 0.0151	4.7116 ± 0.0144	4.5697 ± 0.0155
R9	4.5150 ± 0.0157	4.7396 ± 0.0168	4.7271 ± 0.0161	4.5679 ± 0.0180
R10	4.5113 ± 0.0155	4.7181 ± 0.0170	4.7093 ± 0.0148	4.5510 ± 0.0173
EST	4.3935	4.6165	4.6920	4.5644
ε_{max}	0.1593 (3.5%)	0.1542 (3.2%)	0.0629 (1.3%)	0.0307 (0.7%)

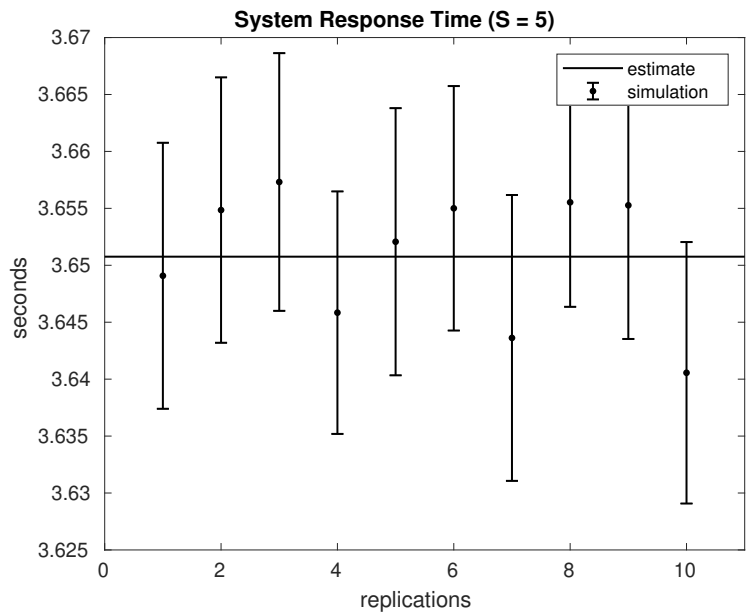
Table: tempo di risposta sistema classe 2

Risultati: Tempo di Risposta Sistema







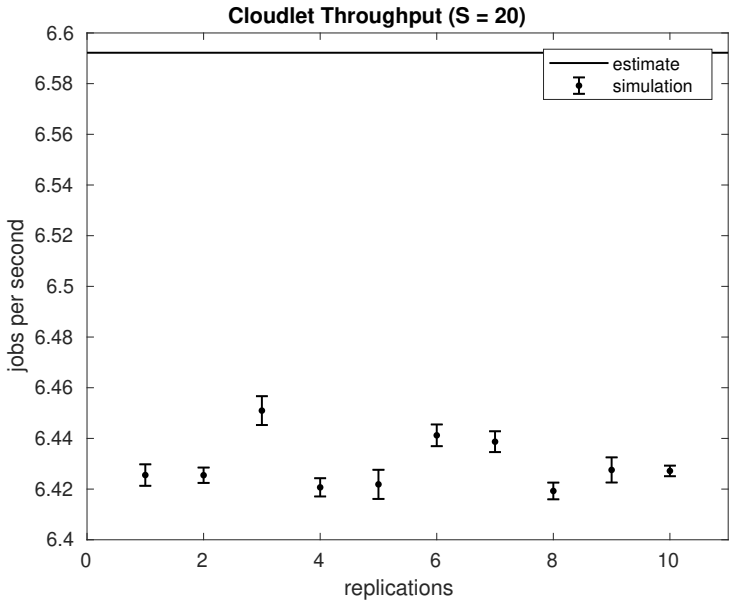


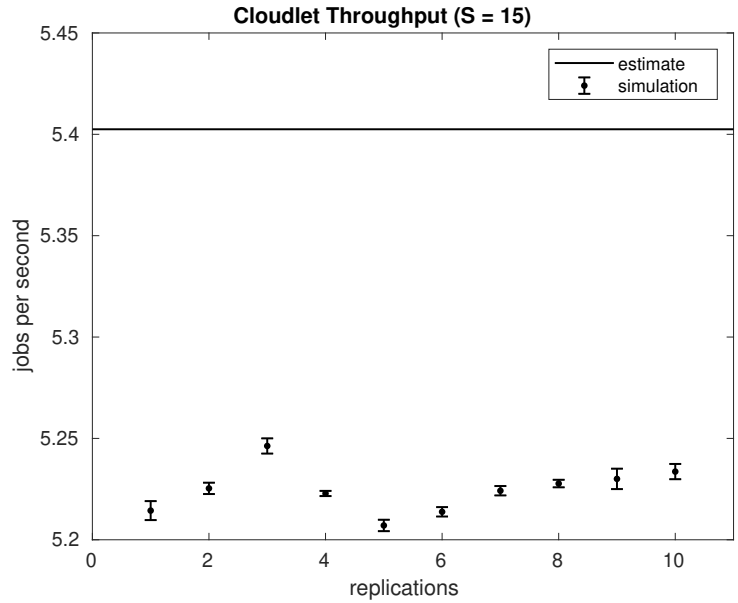
Risultati: Tempo di Risposta Sistema

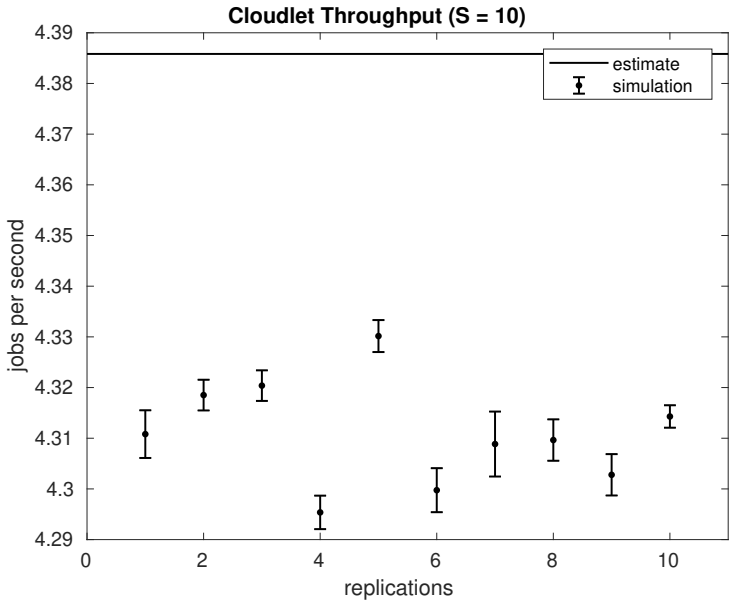
	$S = 20$	$S = 15$	$S = 10$	$S = 5$
R1	3.6266 ± 0.0096	3.7575 ± 0.0109	3.7460 ± 0.0129	3.6491 ± 0.0117
R2	3.6269 ± 0.0121	3.7588 ± 0.0110	3.7527 ± 0.0124	3.6548 ± 0.0117
R3	3.6307 ± 0.0133	3.7611 ± 0.0122	3.7564 ± 0.0114	3.6573 ± 0.0113
R4	3.6124 ± 0.0110	3.7579 ± 0.0110	3.7412 ± 0.0105	3.6458 ± 0.0106
R5	3.6218 ± 0.0097	3.7675 ± 0.0126	3.7478 ± 0.0103	3.6521 ± 0.0117
R6	3.6197 ± 0.0125	3.7606 ± 0.0124	3.7509 ± 0.0115	3.6550 ± 0.0107
R7	3.6344 ± 0.0119	3.7539 ± 0.0119	3.7427 ± 0.0120	3.6436 ± 0.0126
R8	3.6318 ± 0.0103	3.7459 ± 0.0095	3.7398 ± 0.0098	3.6555 ± 0.0092
R9	3.6193 ± 0.0109	3.7603 ± 0.0119	3.7530 ± 0.0114	3.6553 ± 0.0117
R10	3.6152 ± 0.0100	3.7426 ± 0.0102	3.7372 ± 0.0103	3.6406 ± 0.0115
EST	3.5465	3.6825	3.7286	3.6508
ε_{max}	0.0999 (2.7%)	0.0976 (2.6%)	0.0392 (1.0%)	0.0179 (0.5%)

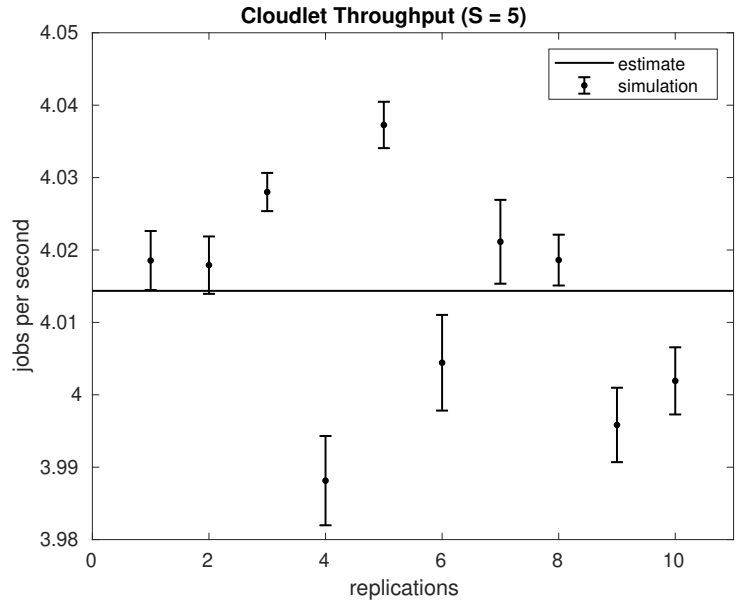
Table: tempo di risposta sistema

Risultati: Throughput Cloudlet









Risultati: Throughput Cloudlet

	$S = 20$	$S = 15$	$S = 10$	$S = 5$
R1	6.4255 ± 0.0042	5.2144 ± 0.0047	4.3108 ± 0.0047	4.0185 ± 0.0041
R2	6.4255 ± 0.0030	5.2254 ± 0.0028	4.3185 ± 0.0030	4.0179 ± 0.0040
R3	6.4510 ± 0.0057	5.2463 ± 0.0037	4.3204 ± 0.0030	4.0280 ± 0.0026
R4	6.4207 ± 0.0036	5.2228 ± 0.0013	4.2954 ± 0.0033	3.9881 ± 0.0062
R5	6.4219 ± 0.0057	5.2071 ± 0.0028	4.3302 ± 0.0032	4.0373 ± 0.0032
R6	6.4412 ± 0.0043	5.2138 ± 0.0023	4.2997 ± 0.0043	4.0044 ± 0.0066
R7	6.4387 ± 0.0041	5.2242 ± 0.0023	4.3089 ± 0.0064	4.0211 ± 0.0058
R8	6.4193 ± 0.0033	5.2277 ± 0.0019	4.3096 ± 0.0041	4.0186 ± 0.0035
R9	6.4276 ± 0.0050	5.2300 ± 0.0050	4.3028 ± 0.0041	3.9958 ± 0.0051
R10	6.4272 ± 0.0021	5.2336 ± 0.0038	4.3143 ± 0.0022	4.0019 ± 0.0046
EST	6.5922	5.4025	4.3858	4.0144
ε_{max}	0.1696 (2.6%)	0.1926 (3.7%)	0.0872 (2.0%)	0.0261 (0.6%)

Table: throughput cloudlet

Distribuzione Throughput Cloudlet