



Progetto di Architetture Avanzate di Networking e Sistemi Wireless

A.A 2013/2014

di

Calogero Lo Bue

Filippo Mascolo

Francesco Porcu

Obiettivo

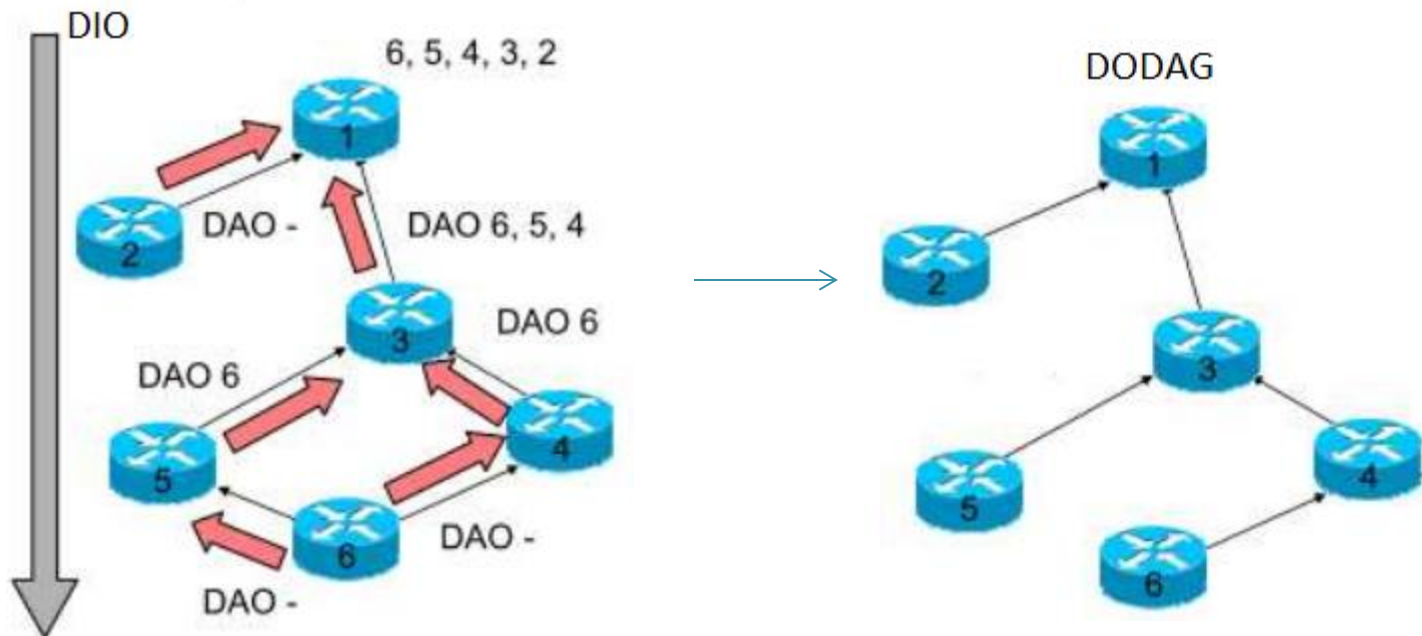
- Realizzazione della *Objective Function* composta (***Hop Count + Residual Energy***) proposta nel paper “*Design of primary and composite routing metrics for RPL-compliant Wireless Sensor Network*”
- Studio simulativo della *Objective Function* e confronto dei risultati con *ETX*

RPL

- Protocollo di comunicazione per reti di sensori
- Minimizza una certa *objective function* (Hop Count, Residual Energy, ETX, ...)

Creazione DODAG

1. Inondazione rete con messaggi DIO
2. Risposta con messaggi DAO
3. Creazione DODAG



Trickle Algorithm

- Gestisce la fase di inondazione dei DIO
- Limita disseminazione DIO
- Evita i duplicati in un dato intervallo
- Parametri:
 - *Trickle Time* I_{min} (rate di trasmissione)
 - *Supressing value* k (tolleranza duplicati)

Objective function composta

$$\text{Rank}_i = \text{Rank}_{i-1} + \text{Costo}_{\text{HC}} + \text{Costo}_{\text{RE}}$$

$$\text{Costo}_{\text{HC}} = \text{MIN_HOP_RANK_INCREASE} * \alpha$$

$$\text{Costo}_{\text{RE}} = \text{MIN_HOP_RANK_INCREASE} * \left(\frac{\text{consumed energy}}{\text{max consumed energy}} * 10 \right) * \beta$$

- Rank₀ = Rank della radice = MIN_HOP_RANK_INCREASE = 256
- MIN_HOP_RANK_INCREASE = 256
- consumed energy = messaggi inviati * costo messaggio
- Max consumed energy = carica totale batteria

Assunzioni

- I nodi non muoiono mai
 - Solo il preferred parent nel parent set
- Scenario 'Uniform' con 100 nodi
- Energia consumata in trasmissione

Analisi simulatore: parametri

- Parametri simulazione
 - $I = 5, 7$
 - $K = 3, 5, 7$
 - Parent_set = 1
 - Reset_time = 8280
 - Reset_type = true, false
 - OF_type = ENERGY, MRHOF, OF0
- Valori dei pesi
 - $\alpha = 0.1, 0.3, 0.5, 0.7, 0.9$
 - $\beta = 0.9, 0.7, 0.5, 0.3, 0.1$
- Numero di run = 40
- Capacità batteria = 500'000 nJ

Metriche analizzate

- **Rank Changed**: numero di cambiamenti di rank per i vari nodi
- **Routing Shortest Stretch**: differenza tra costo del percorso scelto per arrivare dal nodo alla radice e percorso ottimo (calcolato a priori secondo la metrica ETX)
- **RPL Collision**: numero di collisioni negli invii di pacchetti
- **RPL Loss**: numero di perdite dei pacchetti
- **RPL Received**: numero di pacchetti ricevuti dai nodi
- **RPL Sended**: numero di pacchetti inviati dai vari nodi

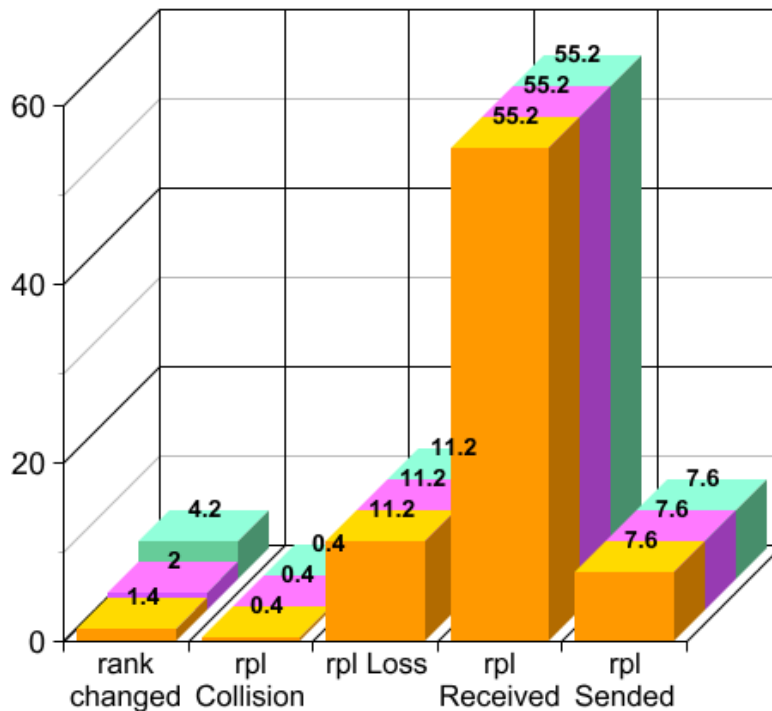
Analisi simulatore: osservazioni

- Reset Type (false, true):
 - Quando **true** ad ogni cambiamento di rank il protocollo Trickle reimposta l'intervallo al valore di I_{min} e resetta il contatore c di messaggi inviati
 - Con **false** invece la rete non resetta tali valori ad ogni cambiamento di rank
 - Nessuna differenza tra le varie Objective Function

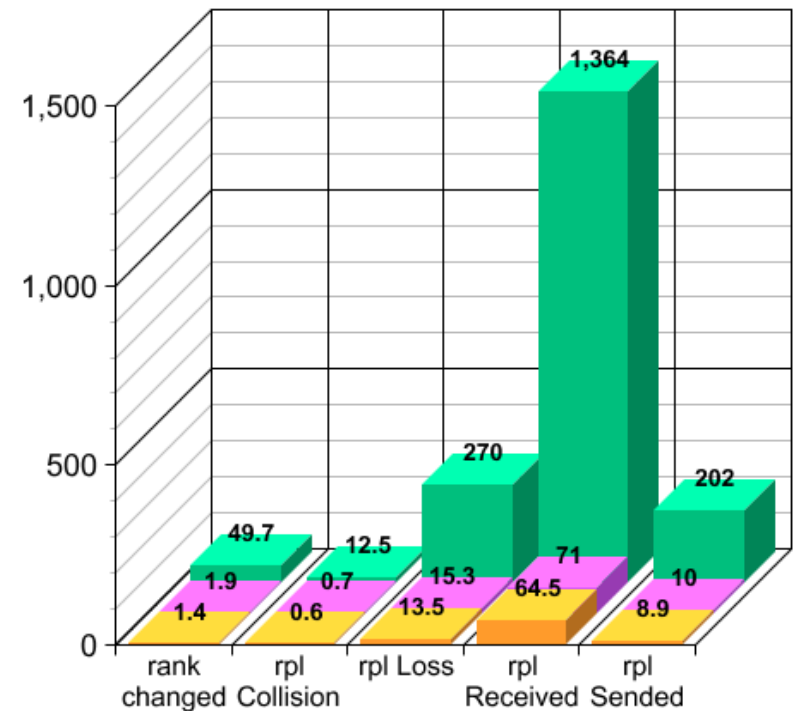
Analisi simulatore: grafici

- Grafici con valori AVG
 - quelli MAX continuano ad avere lo stesso andamento

(I = 7, K = 3) (A = 0.5, B = 0.5) (reset_type = FALSE)



(I = 7, K = 3) (A = 0.5, B = 0.5) (reset_type = TRUE)

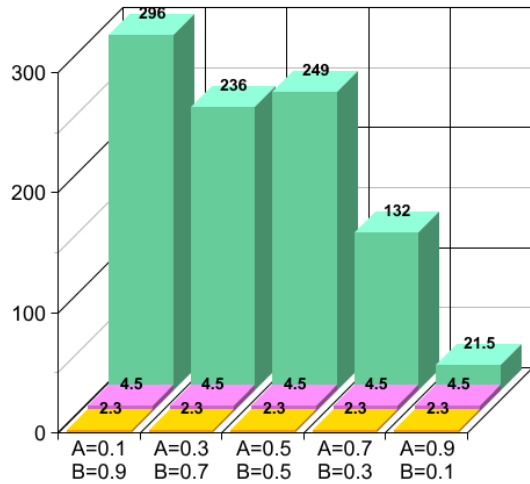


Scenario 1: parametri α e β

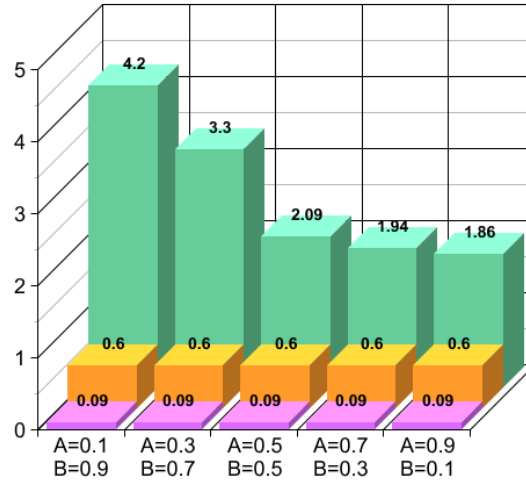
- Per qualsiasi combinazione di «i» e «k»
 - Nei grafici usiamo come esempio la combinazione $i=7$, $k=3$
- Aumentando « α » e diminuendo « β » si ottengono miglioramenti
 - Sia a livello Energetico che di Shortest_stretch
 - Più peso a HC rispetto a Energy
 - Meno variazioni di Rank

Scenario 1: grafici

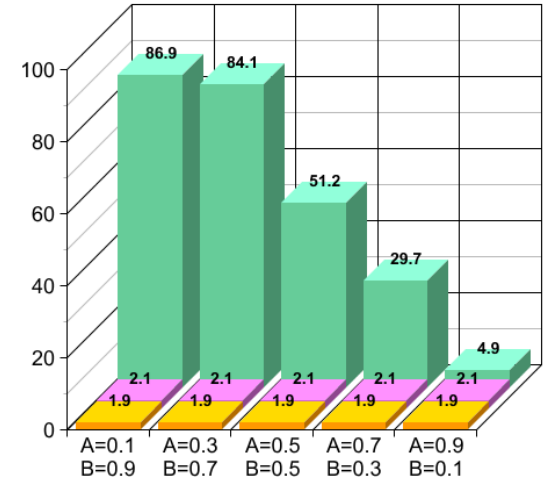
RANK CHANGED (MAX)



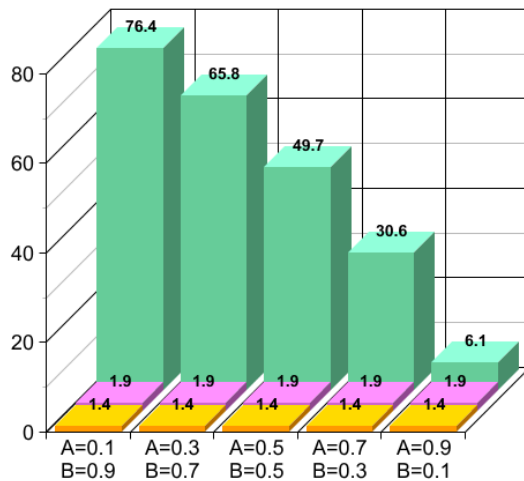
ROUTING SHORTEST STRETCH (MAX)



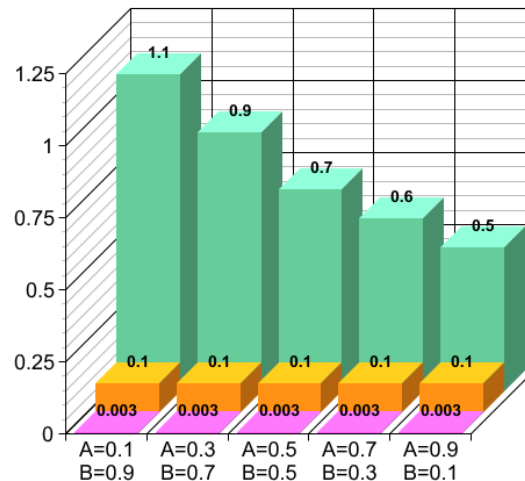
RPL COLLISION (MAX)



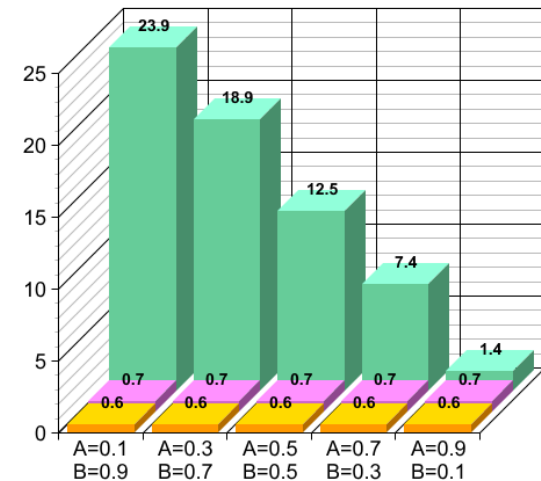
RANK CHANGED (AVG)



ROUTING SHORTEST STRETCH (AVG)

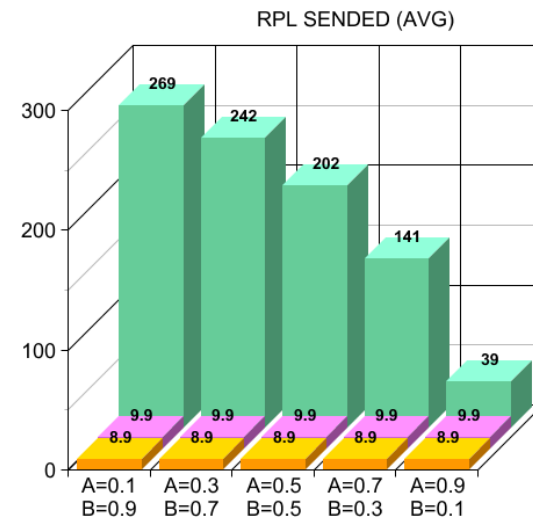
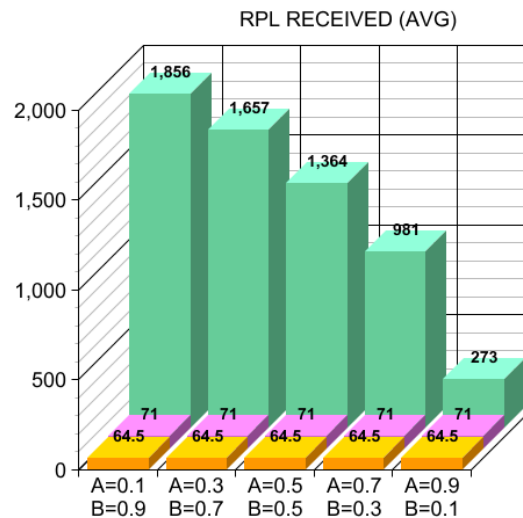
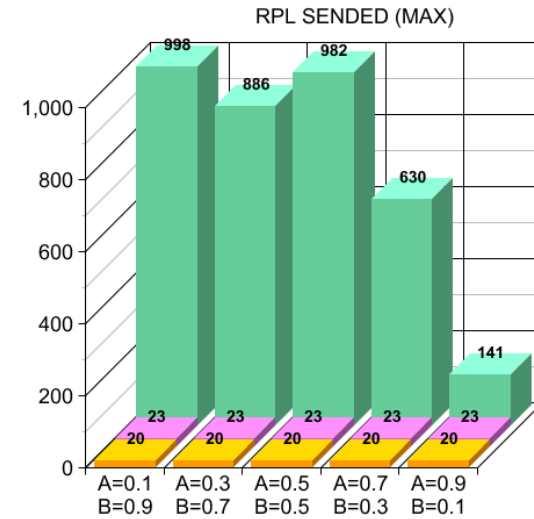
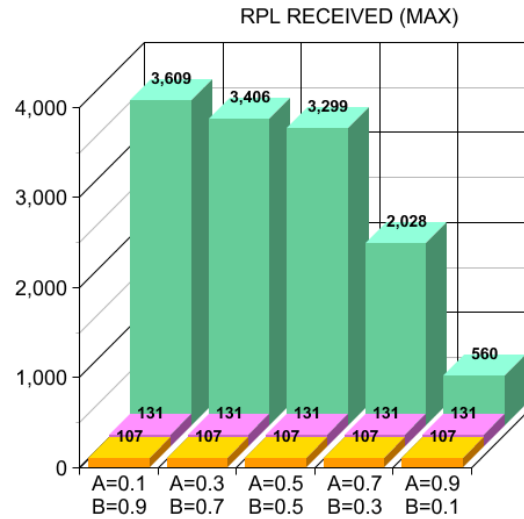
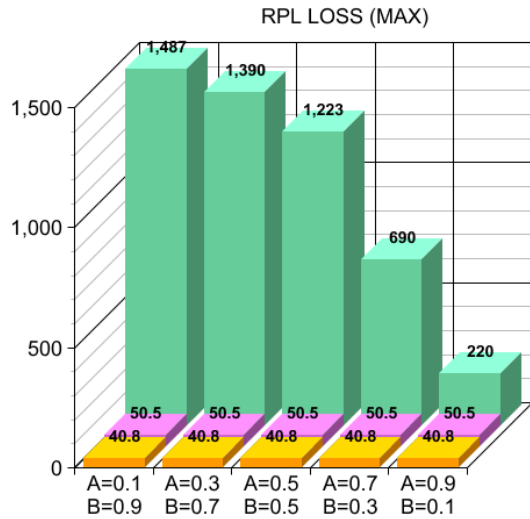


RPL COLLISION (AVG)



- HC+RE
- OF0
- MRHOF

Scenario 1: grafici



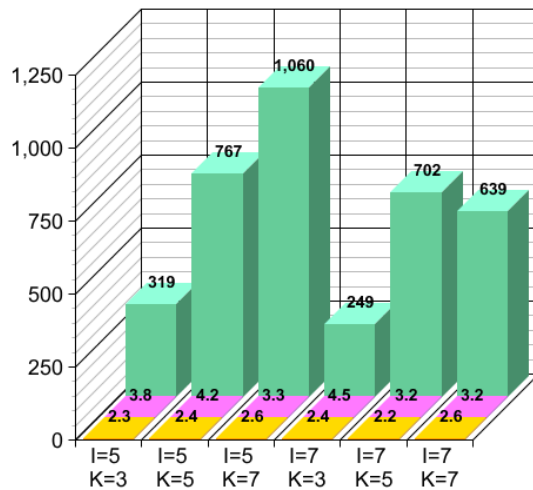
■ HC+RE
■ OF0
■ MRHOF

Scenario 2: parametri i e k

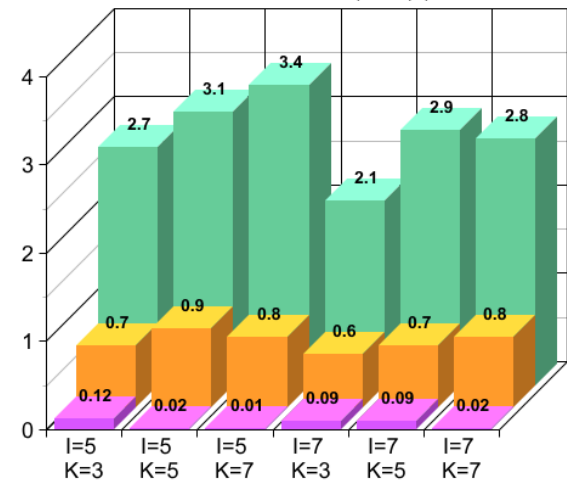
- Teniamo fissi « α » e « β »
- Variamo « i » e « k »
- Cosa ci aspettiamo:
 - « i » alto , « k » basso: meno collisioni e più soppressione
 - miglioramenti dal punto di vista energetico
 - peggioramenti per lo `shortest_stretch`
 - « i » basso , « k » alto: più collisioni e meno soppressione
 - peggioramenti dal punto di vista energetico
 - miglioramenti per lo `shortest_stretch`

Scenario 2: grafici

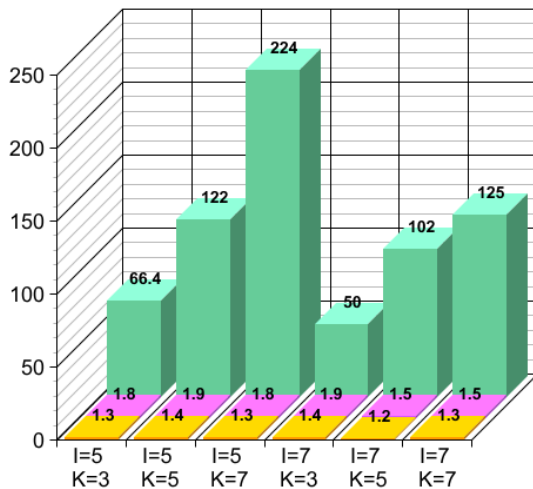
RANK CHANGED (MAX) (A = 0.5 , B = 0.5)



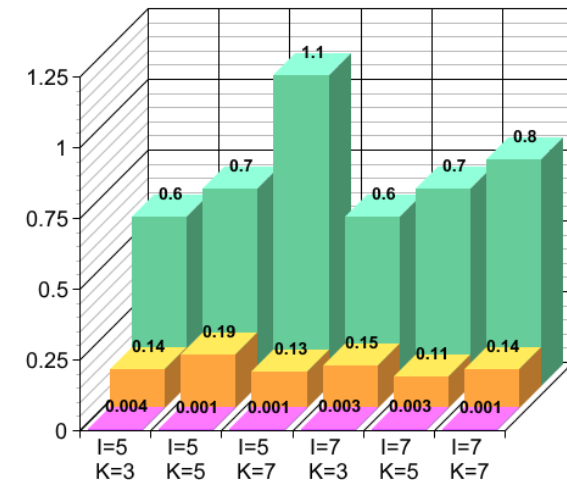
ROUTING SHORTEST STRETCH (MAX) (A = 0.5 , B = 0.5)



RANK CHANGED (AVG) (A = 0.5 , B = 0.5)



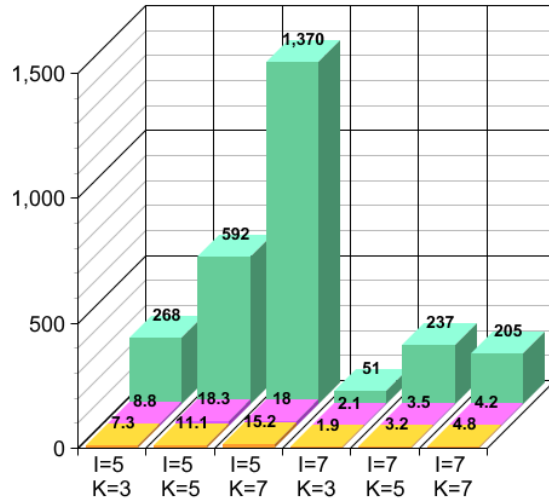
ROUTING SHORTEST STRETCH (AVG) (A = 0.5 , B = 0.5)



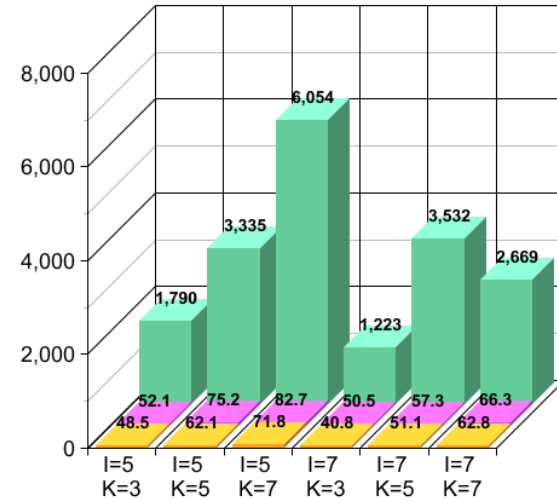
- HC+RE
- OF0
- MRHOF

Scenario 2: grafici

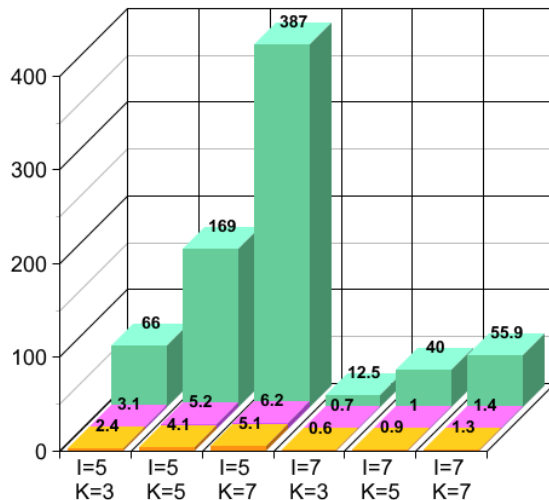
RPL COLLISION (MAX) (A = 0.5 , B = 0.5)



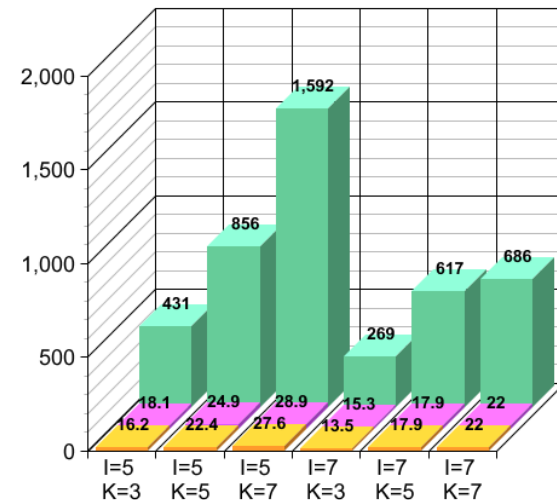
RPL LOSS (MAX) (A = 0.5 , B = 0.5)



RPL COLLISION (AVG) (A = 0.5 , B = 0.5)



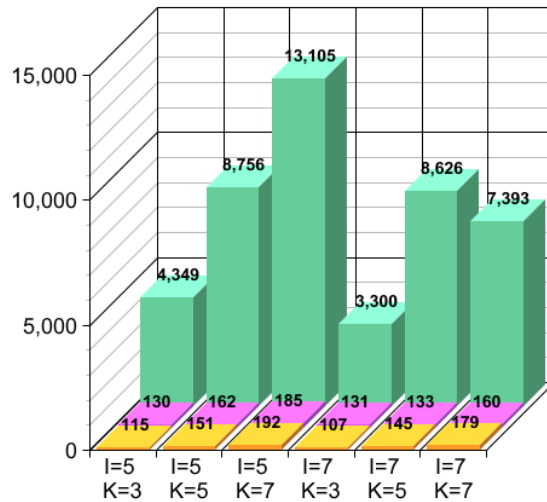
RPL LOSS (AVG) (A = 0.5 , B = 0.5)



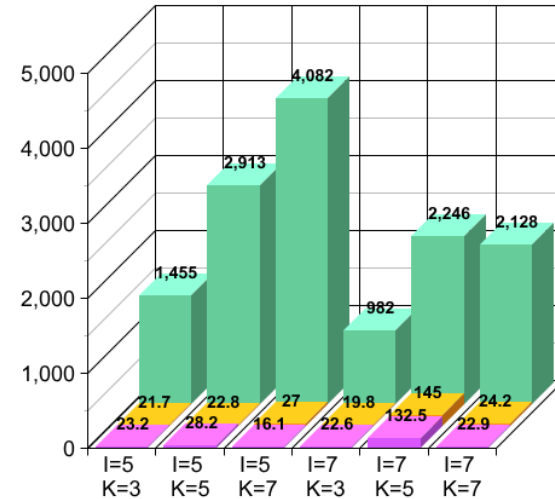
- HC+RE
- OF0
- MRHOF

Scenario 2: grafici

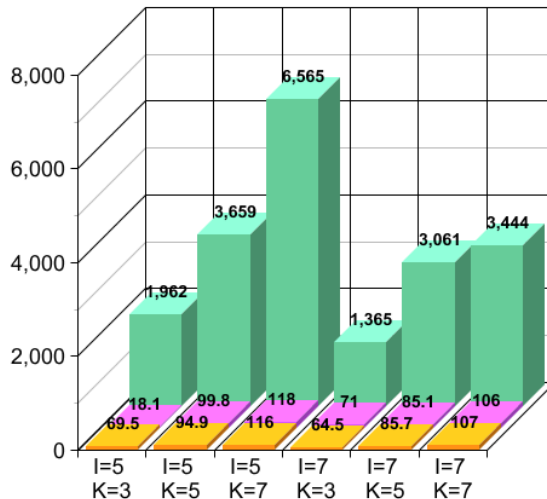
RPL RECEIVED (MAX) (A = 0.5 , B = 0.5)



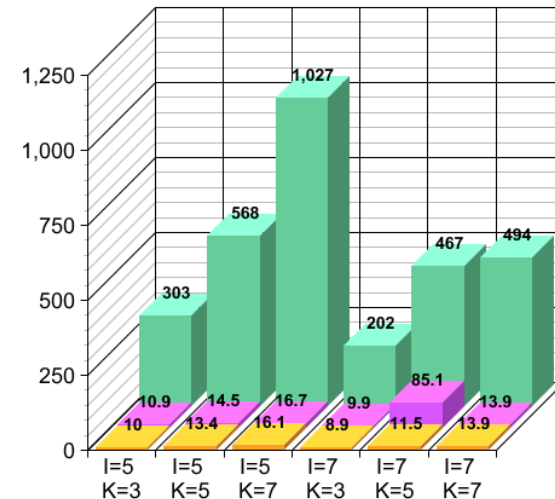
RPL SENDEE (MAX) (A = 0.5 , B = 0.5)



RPL RECEIVED (AVG) (A = 0.5 , B = 0.5)



RPL SENDEE (AVG) (A = 0.5 , B = 0.5)



- HC+RE
- OF0
- MRHOF

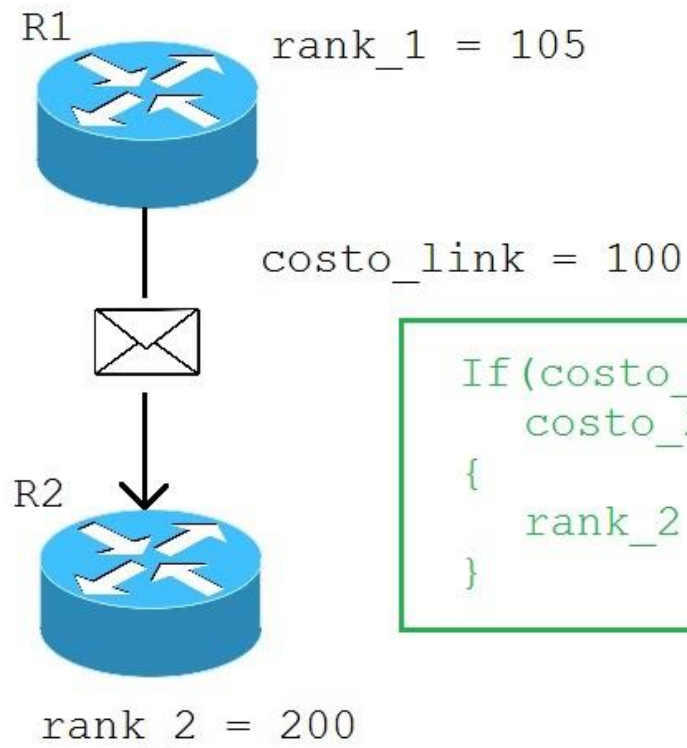
Scenario 2: energy vs shortest stretch

- al variare di i e k :
 - **Energy**: la configurazione $i=7, k=3$ è migliore di $i=5, k=7$ (come previsto)
 - **Shortest Stretch**: la configurazione $i=7, k=3$ è migliore di $i=5, k=7$
(comportamento non previsto delle varie configurazioni causato dai troppi messaggi, dalle collisioni e dalle perdite)

Scenario 2: conclusioni

- Simulare solo con *reset_type = true* (false scartata)
- Simulare solo i casi:
 - $I = 5$, $K = 7$ (*worst case*)
 - $I = 7$, $K = 3$ (*best case*)
- **Prossimo step** → inserire controllo sul cambiamento di rank:
 - solo per i cambiamenti del rank del nodo e del *preferred_parent*
 - aumento o diminuzione del rank pari all'1%

Controllo cambiamento rank



```
If(costo_2 < rank_2 - 1% ||  
    costo_2 > rank_2 + 1%)  
{  
    rank_2 = costo_2;  
}
```

costo_2 = 105 + 100

Scenario 3

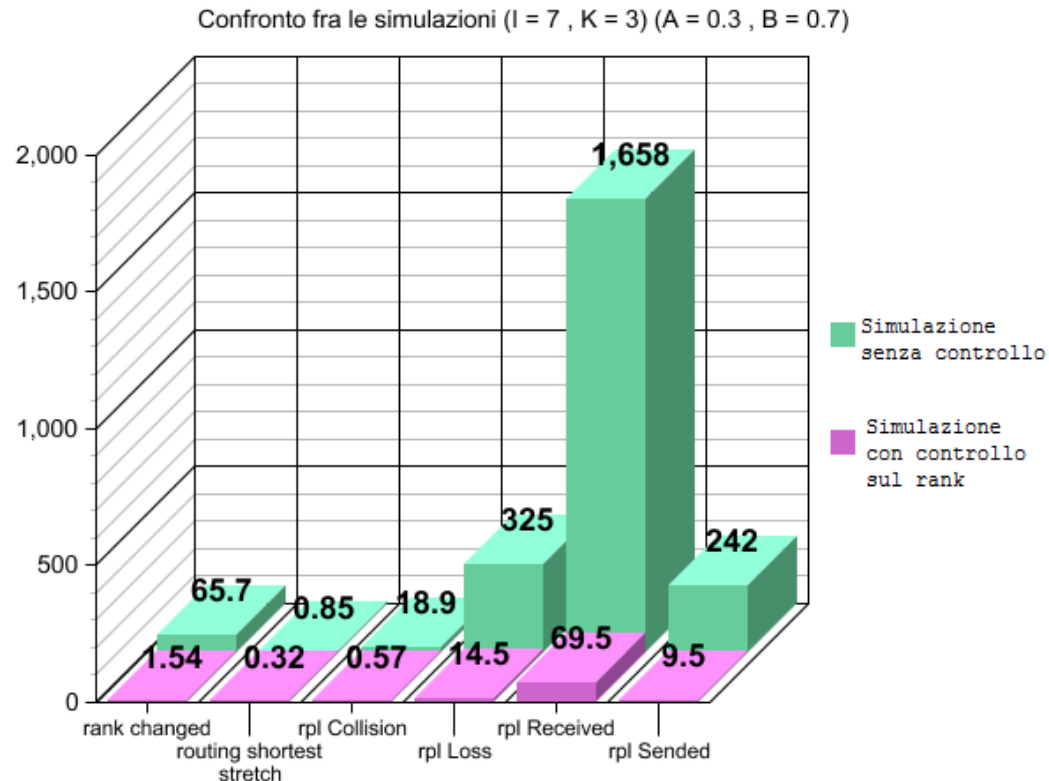
rank 1% - parametri

- Parametri simulazione
 - ($I=5$, $K=7$) , ($I=7$, $K=3$) ←
 - Parent_set = 1
 - Reset_time = 8280
 - Reset_type = true
 - OF_type = ENERGY ←
- Soglia: 1% ←
- Valori dei pesi
 - $\alpha = 0.1, 0.3, 0.5, 0.7, 0.9$
 - $\beta = 0.9, 0.7, 0.5, 0.3, 0.1$
- Numero di run = 40
- Capacità batteria = 500'000 nJ

Scenario 3

rank 1% – miglioramenti ottenuti

- Netto miglioramento rispetto alla simulazione senza il controllo sul rank
 - Numero cambiamenti di rank molto inferiore con conseguente diminuzione di messaggi RPL inviati



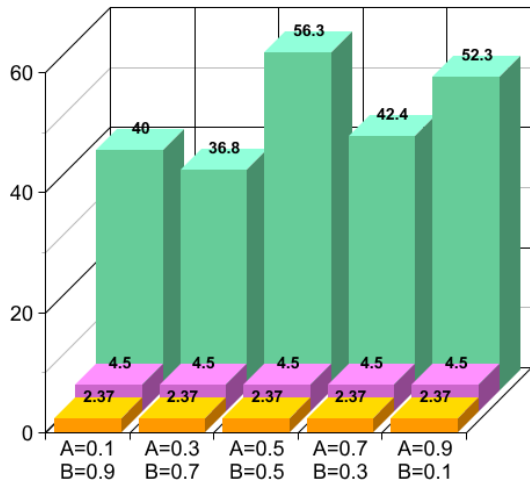
Scenario 3: considerazioni preliminari

- Netti miglioramenti da un punto di vista energetico rispetto alla versione senza controllo
- Capacità batteria troppo elevata rispetto al numero di messaggi inviati per notare differenze evidenti tra le varie configurazioni di α e β
- **Prossimo step** → diminuzione capacità batteria a 100'000 nJ
 - Ci aspettiamo che le prestazioni energetiche peggiorino (cambiamenti dell'1% del rank molto frequenti rispetto ad una batteria maggiore)

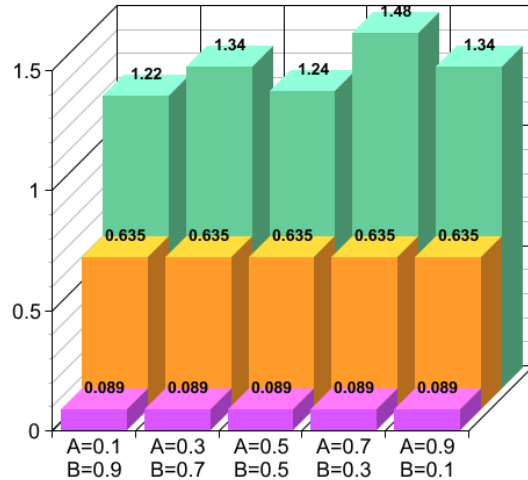
Scenario 4: batteria 100'000 (1%) - best case

- OF0
- HC+RE
- MRHOF

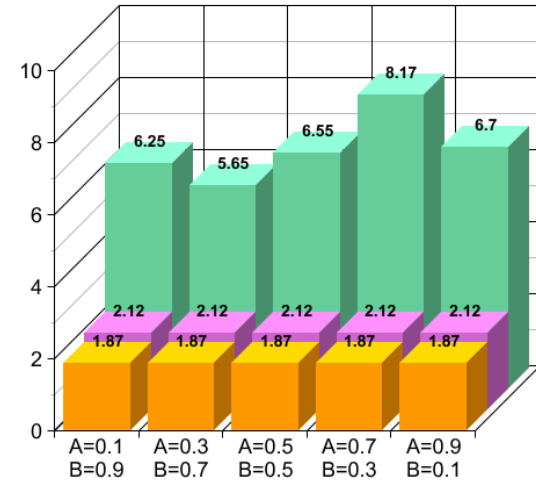
RANK CHANGED (MAX)



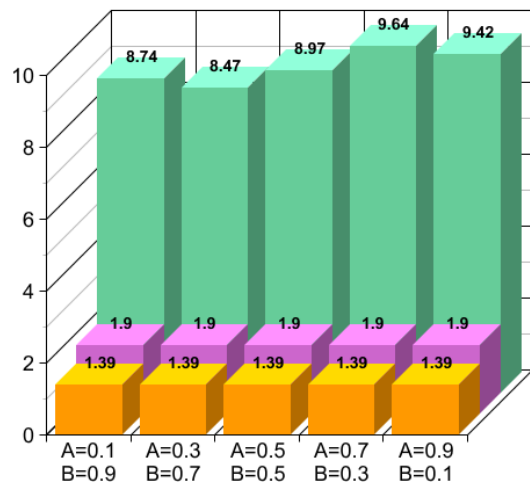
ROUTING SHORTEST STRETCH (MAX)



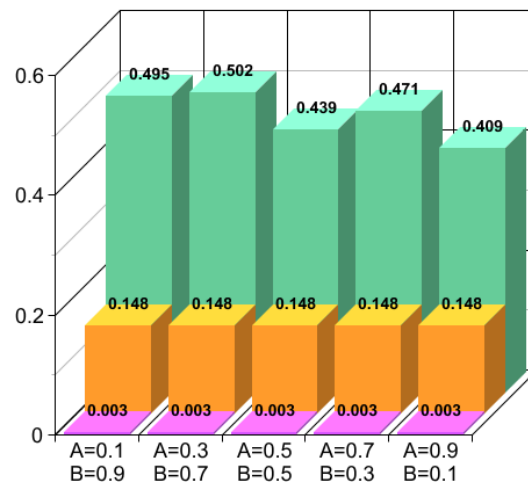
RPL COLLISION (MAX)



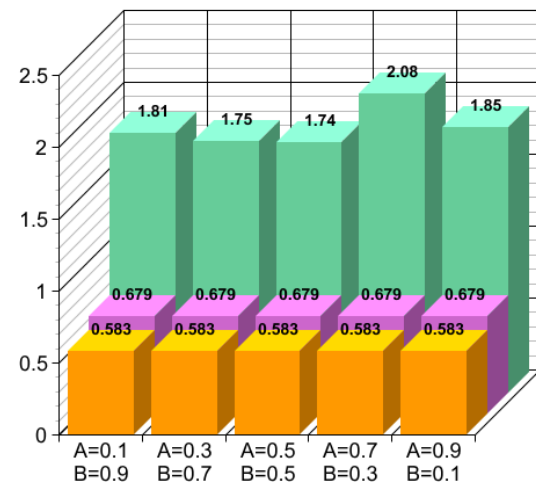
RANK CHANGED (AVG)



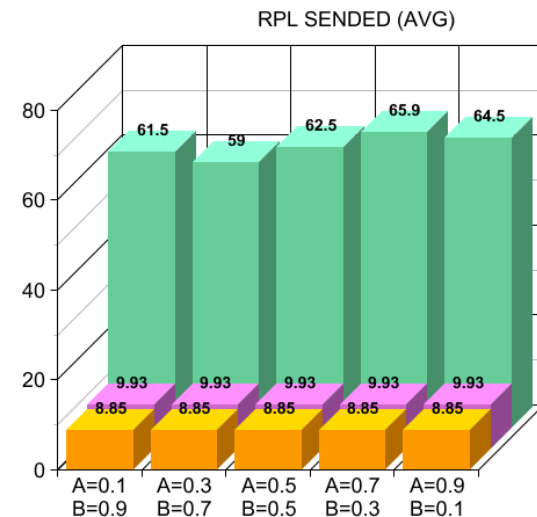
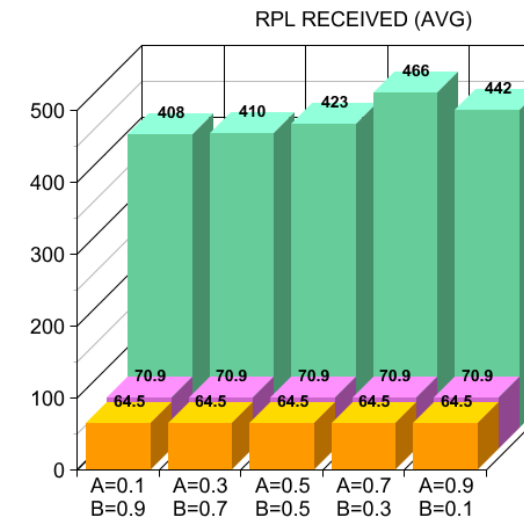
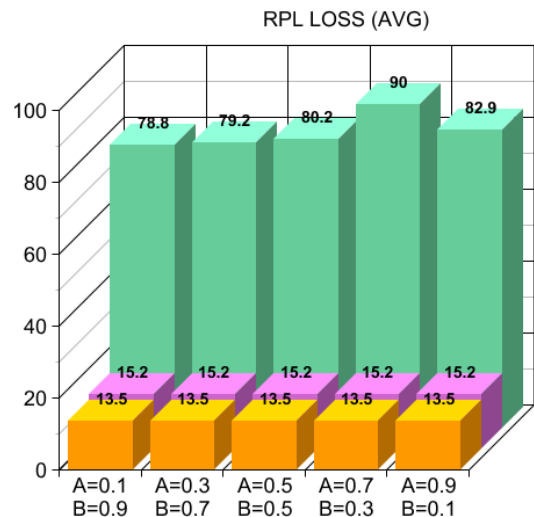
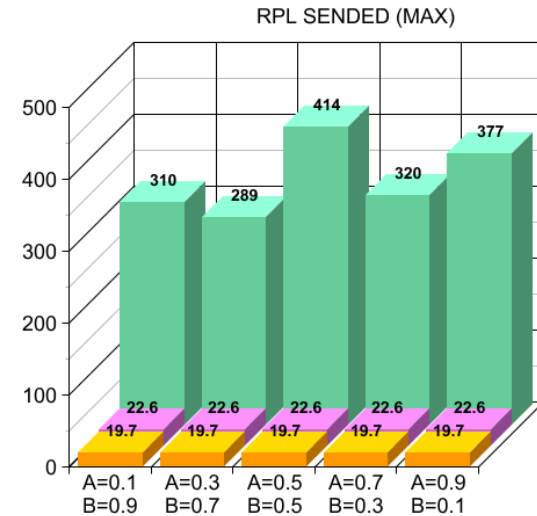
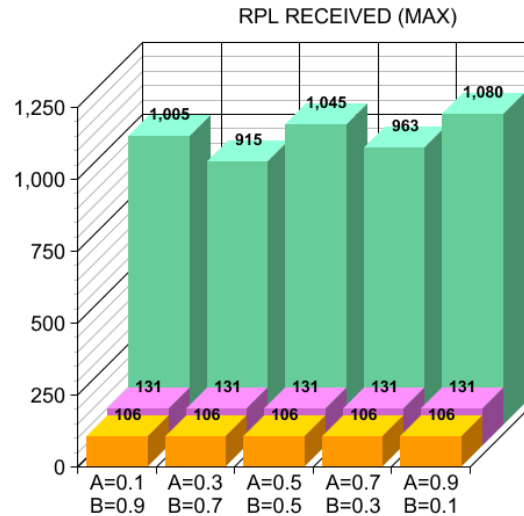
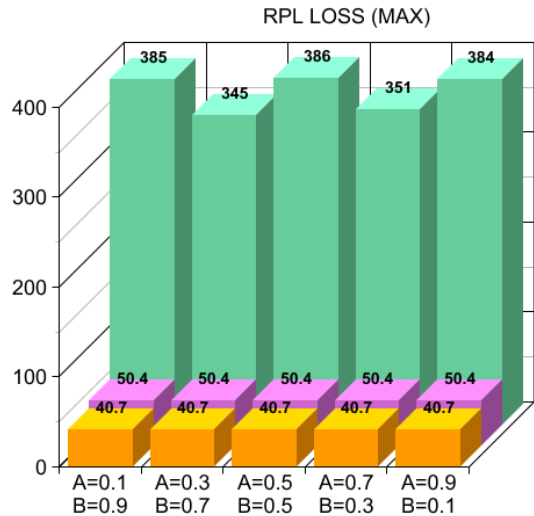
ROUTING SHORTEST STRETCH (AVG)



RPL COLLISION (AVG)

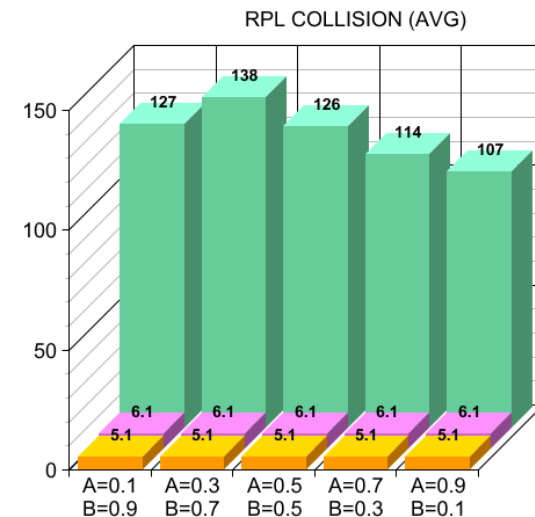
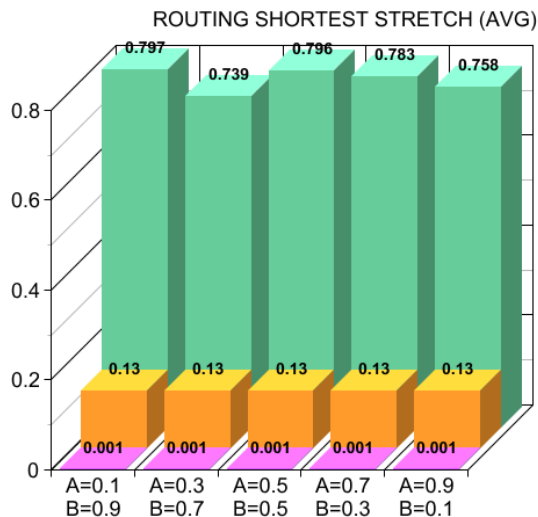
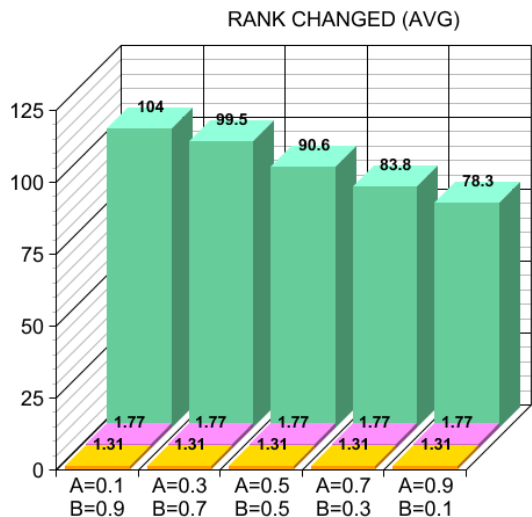
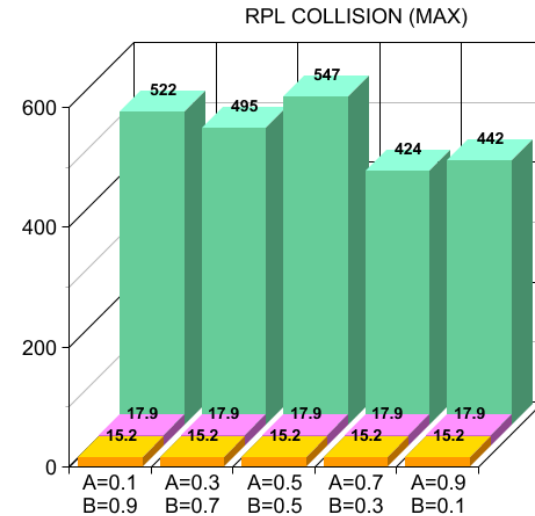
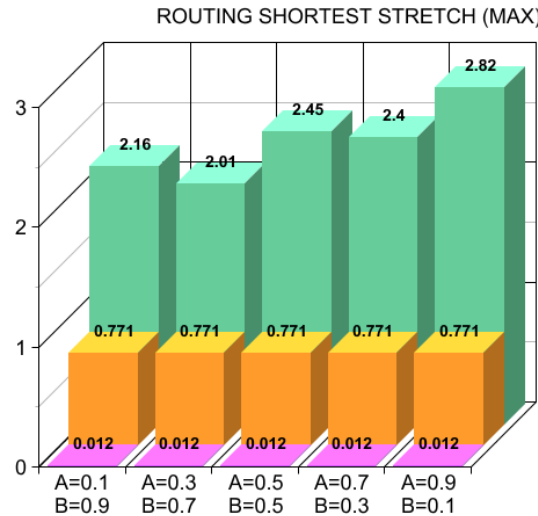
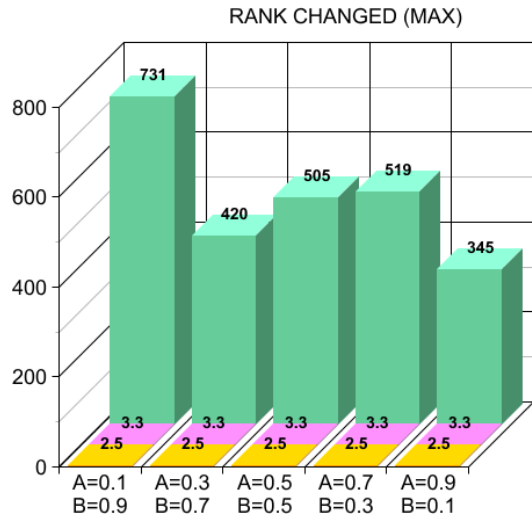


Scenario 4: batteria 100'000 (1%) - best case



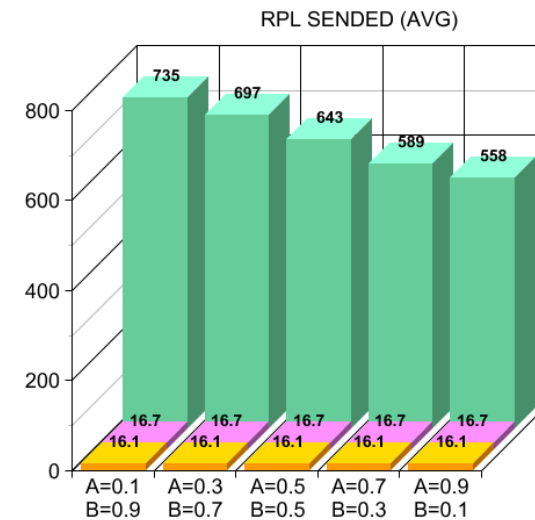
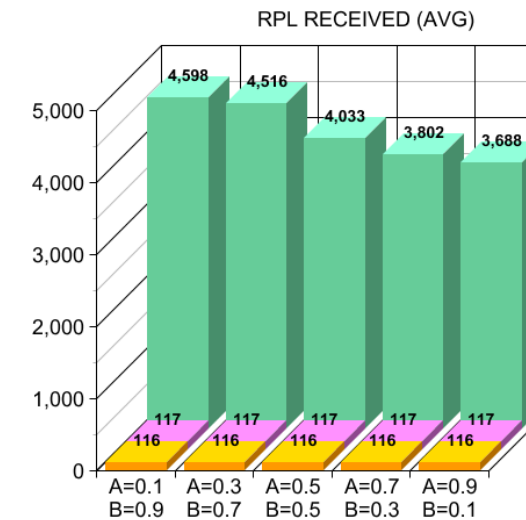
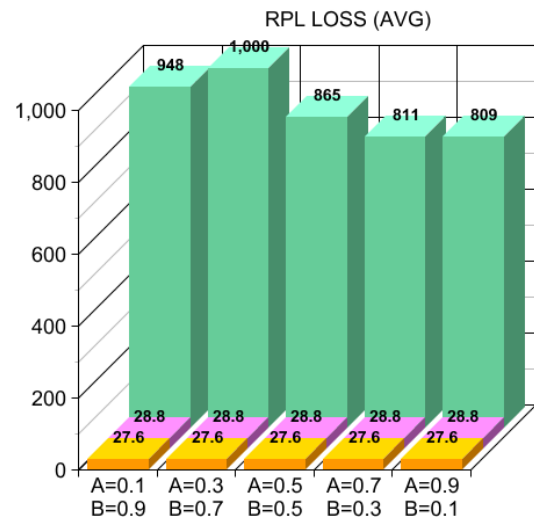
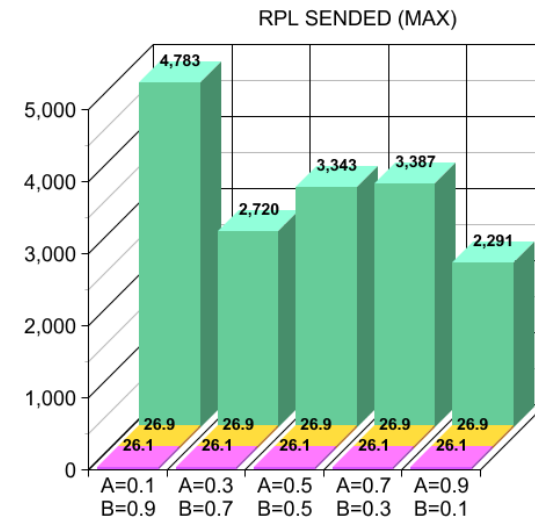
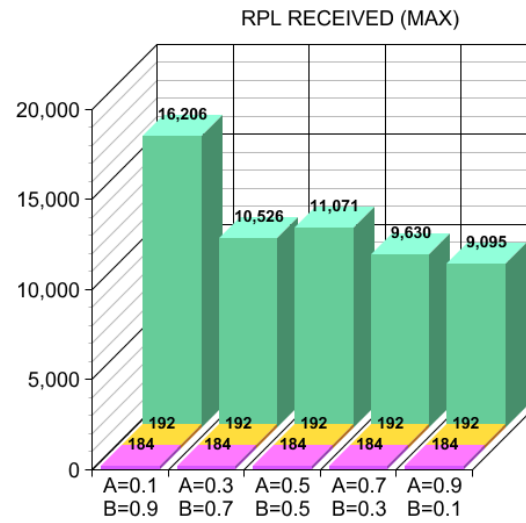
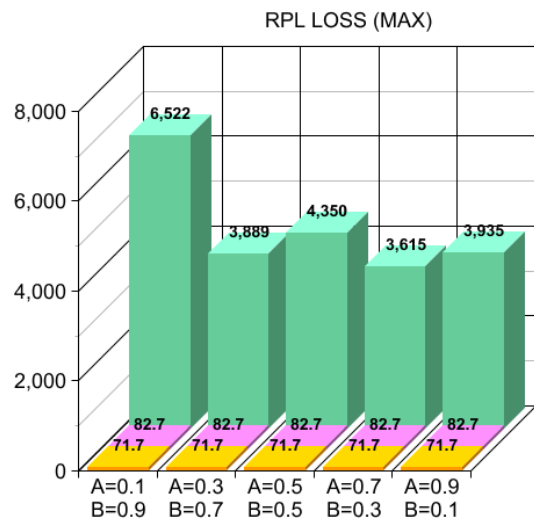
■ OF0
■ HC+RE
■ MRHOF

Scenario 4: batteria 100'000 (1%) - worst case



- OF0
- HC+RE
- MRHOF

Scenario 4: batteria 100'000 (1%) - worst case



- OF0
- HC+RE
- MRHOF

Scenario 3: batteria 500'000 (1%) - conclusioni

- Risultati molto confrontabili sia con MRHOF che OF0
- **Energy**: risultati migliori rispetto a OF0 e molto simili a MRHOF
- **Shortest Stretch**: risultati poco peggiori di MRHOF e di OF0

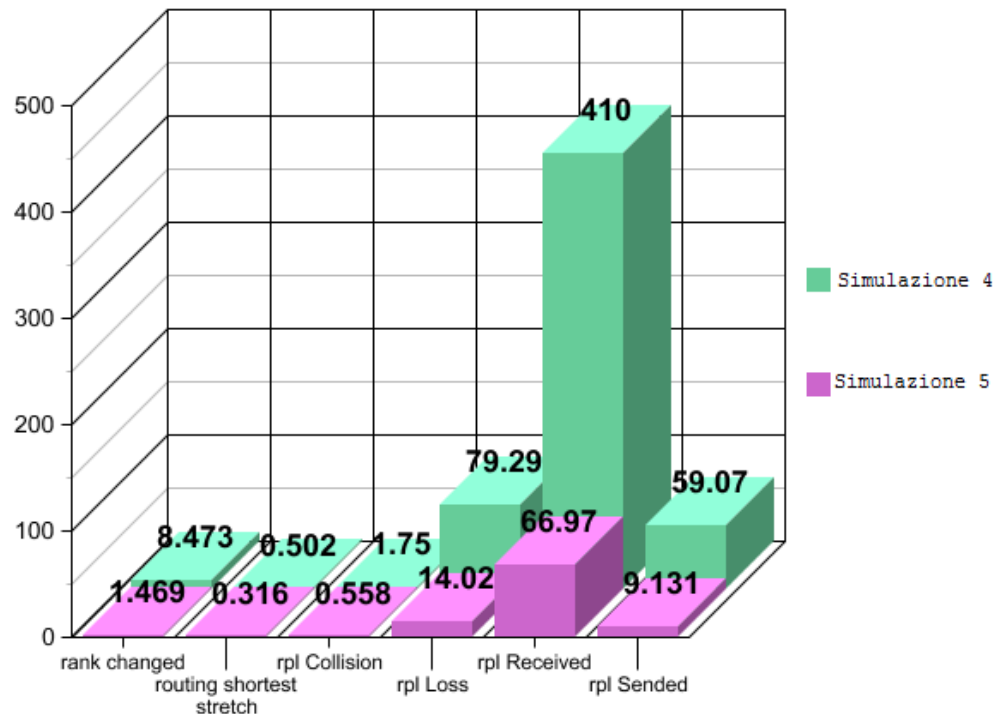
Scenario 4: batteria 100'000 (1%) - conclusioni

- Risultati peggiori ma confrontabili con MRHOF e OF0
- **Energy**: risultati migliori nel «best case» piuttosto che nel «worst case»
- **Shortest Stretch**: risultati migliori nel «best case» rispetto al «worst case» in cui si evidenziano molte collisioni e perdite
- **Prossimo step** → aumento valore della soglia sul controllo del rank al 3%

Scenario 5: rank 3% - miglioramenti ottenuti

- Scenario 4:
soglia 1%, batteria 100'000 nJ
- Scenario 5:
soglia 3%, batteria 100'000 nJ

Confronto fra le simulazioni (I = 7 , K = 3) (A = 0.3 , B = 0.7)



Scenario 5: rank 3% - conclusioni

- **Energy**: netta diminuzione del numero di messaggi inviati
- **Shortest Stretch**: leggero miglioramento dovuto alle minori perdite
- **Prossimo step** → Aggiunta isteresi
 - Aggiornamento rank in base a quello del nuovo preferred_parent solo se migliore del rank attuale di una certa soglia (corrispondente alla variazione del 3% del rank)
 - Ulteriore diminuzione di messaggi inviati rispetto alla configurazione precedente
 - Miglioramenti energetici
 - Peggioramenti dello Shortest Stretch

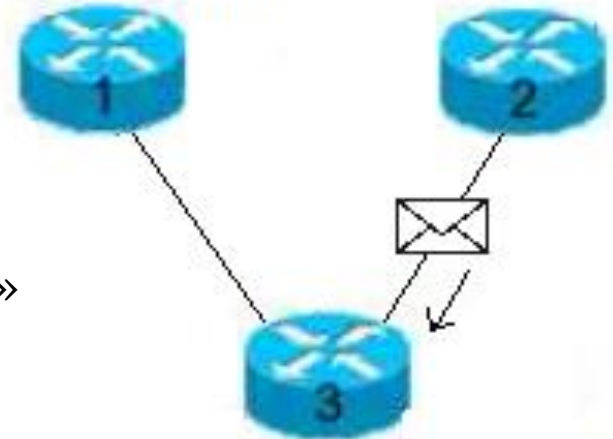
isteresi

```
if(rank2 < rank1) {  
    «cambio_preferred_parent()»  
}
```

```
newRank = calcolo_nuovo_rank();
```

```
if(newRank < myRank - 3%) {  
    «aggiorno_rank()»  
}
```

preferred_parent

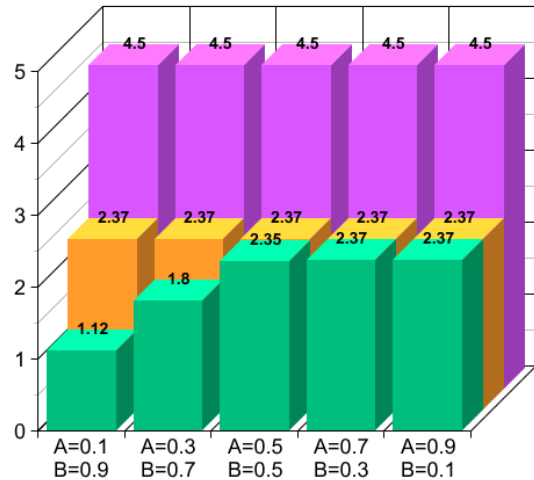


Scenario 6: isteresi - parametri

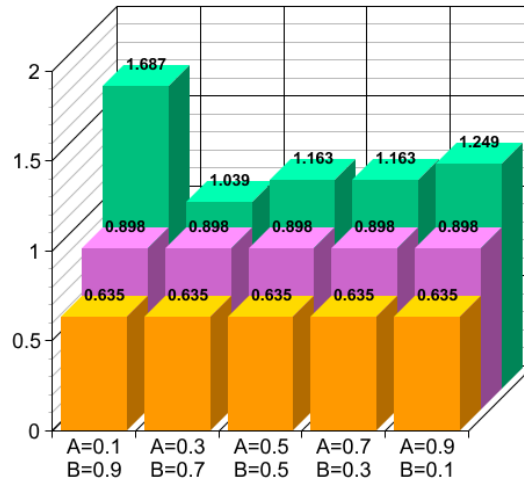
- Parametri simulazione
 - ($I=5$, $K=7$) , ($I=7$, $K=3$)
 - Parent_set = 1
 - Reset_time = 8280
 - Reset_type = true
 - OF_type = ENERGY
- Soglia: 3% ←
- Isteresi ←
- Valori dei pesi
 - $\alpha = 0.1, 0.3, 0.5, 0.7, 0.9$
 - $\beta = 0.9, 0.7, 0.5, 0.3, 0.1$
- Numero di run = 40
- Capacità batteria = 100'000 nJ

Scenario 6: isteresi - best case

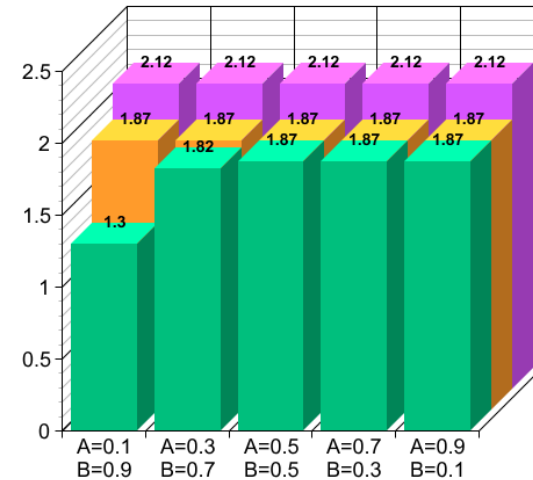
RANK CHANGED (MAX)



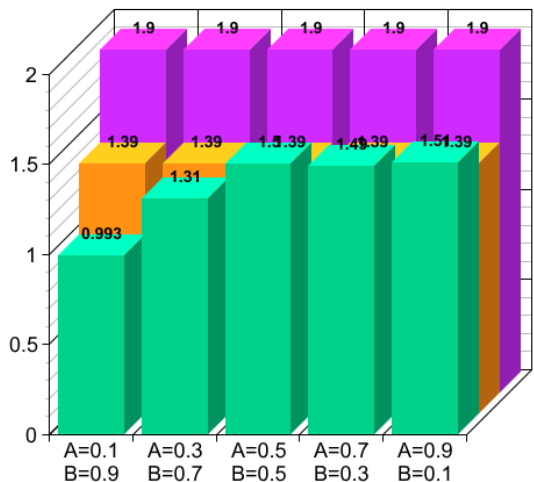
ROUTING SHORTEST STRETCH (MAX)



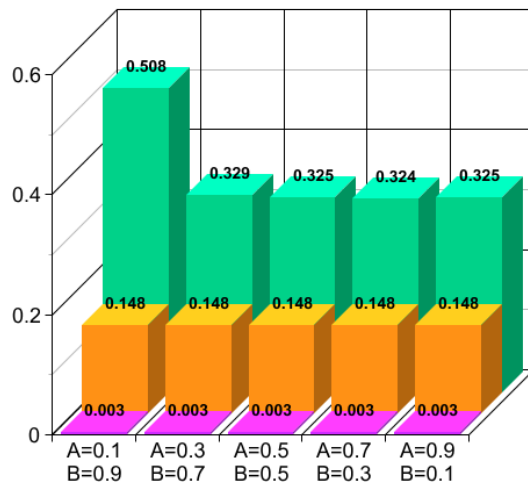
RPL COLLISION (MAX)



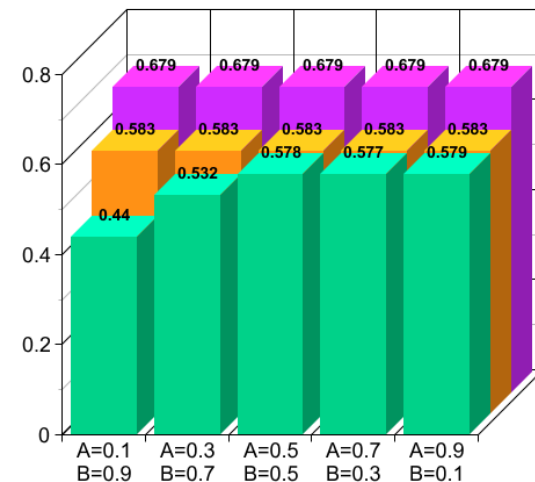
RANK CHANGED (AVG)



ROUTING SHORTEST STRETCH (AVG)



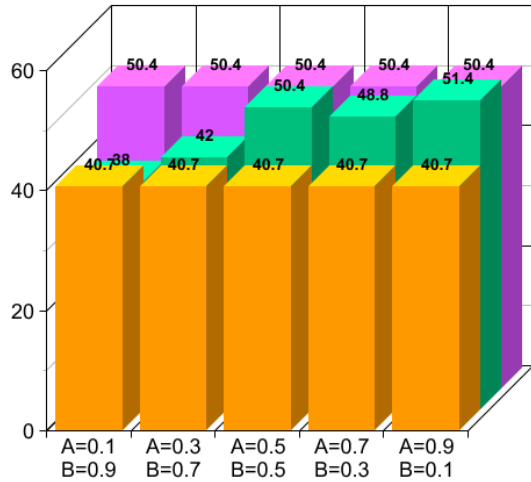
RPL COLLISION (AVG)



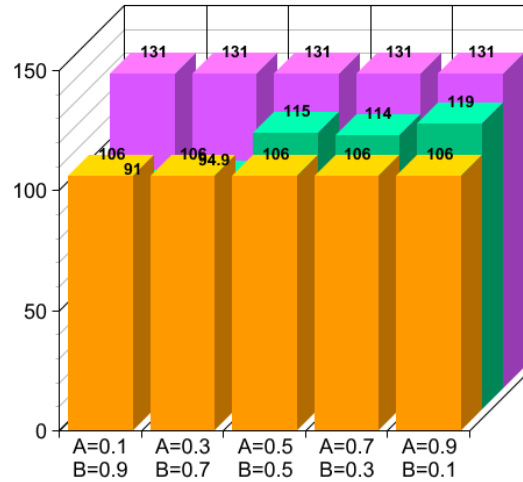
- OF0
- HC+RE
- MRHOF

Scenario 6: isteresi - best case

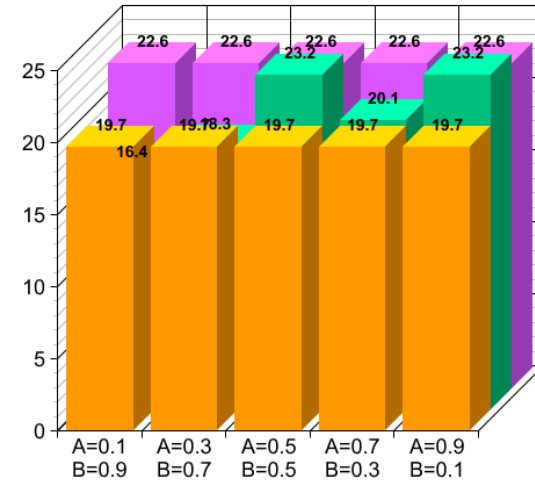
RPL LOSS (MAX)



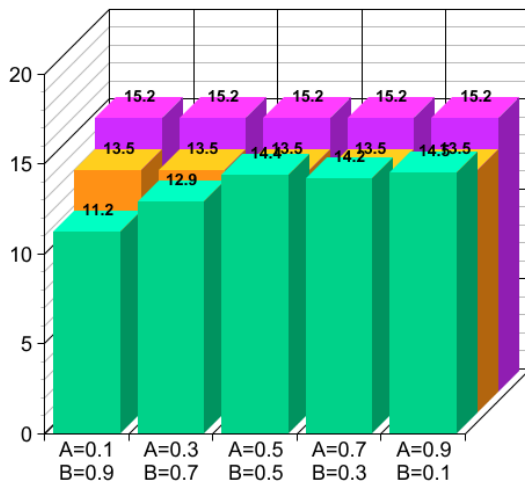
RPL RECEIVED (MAX)



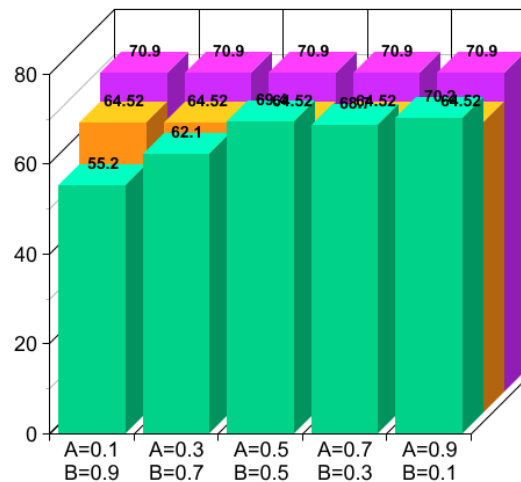
RPL SENDE (MAX)



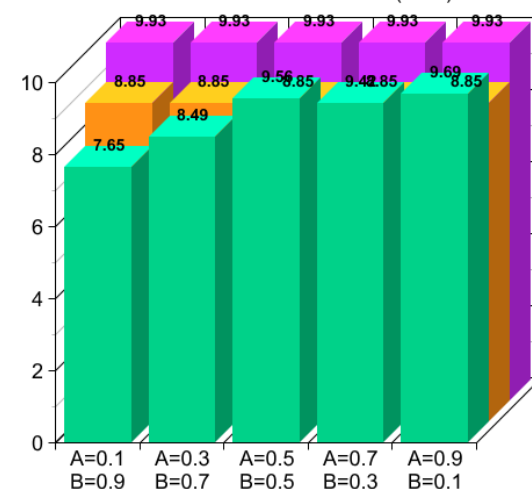
RPL LOSS (AVG)



RPL RECEIVED (AVG)



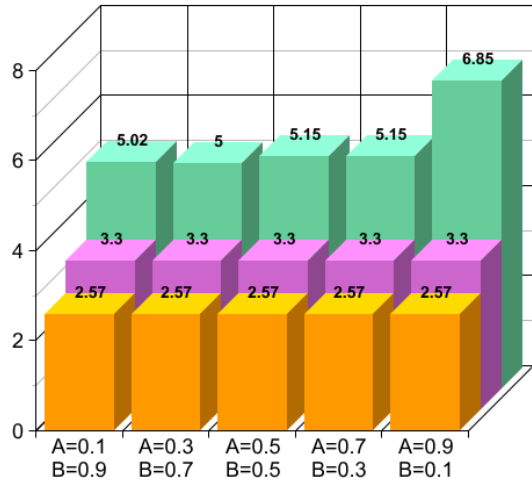
RPL SENDE (AVG)



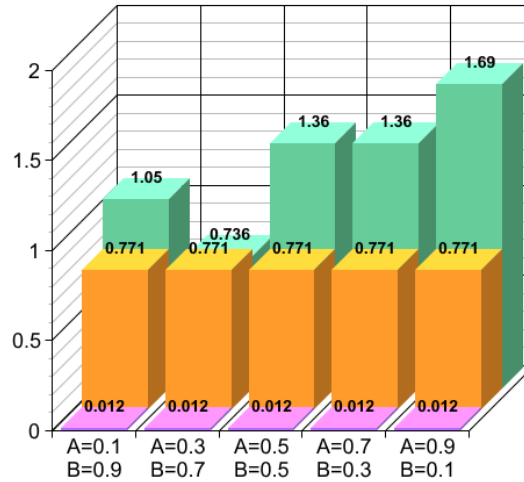
- OF0
- HC+RE
- MRHOF

Scenario 6: isteresi - worst case

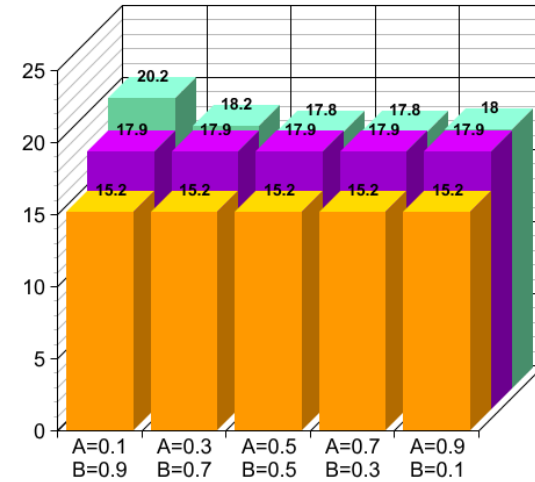
RANK CHANGED (MAX)



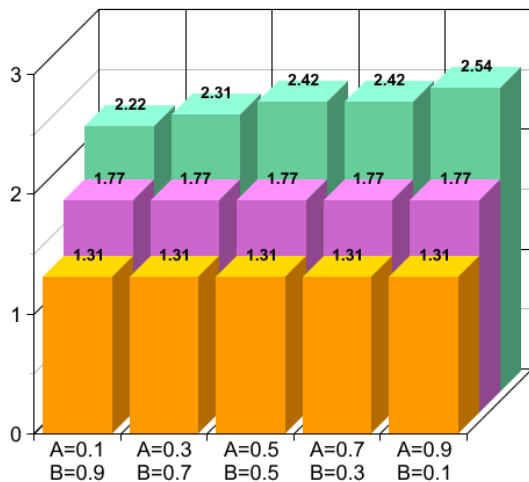
ROUTING SHORTEST STRETCH (MAX)



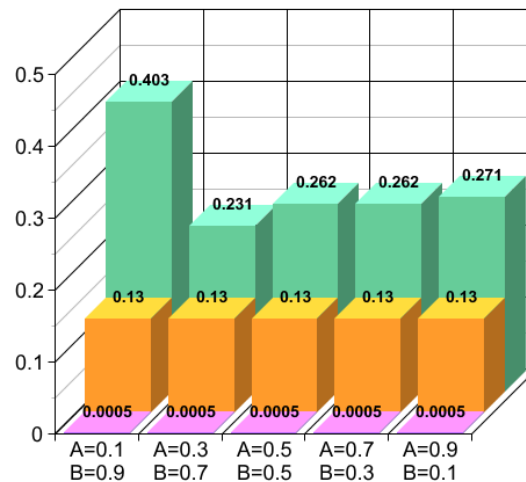
RPL COLLISION (MAX)



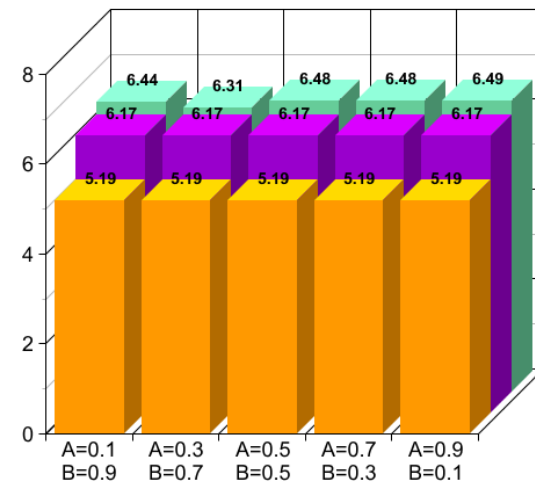
RANK CHANGED (AVG)



ROUTING SHORTEST STRETCH (AVG)



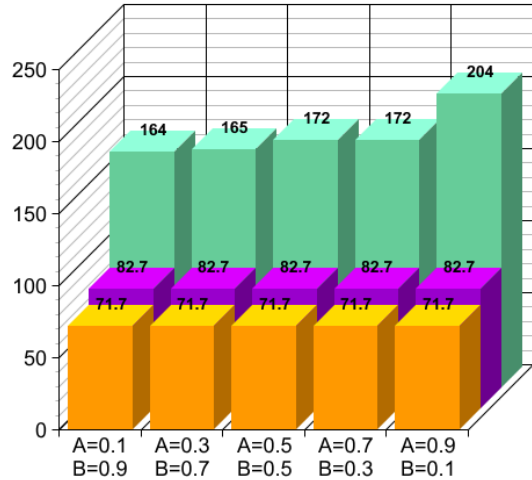
RPL COLLISION (AVG)



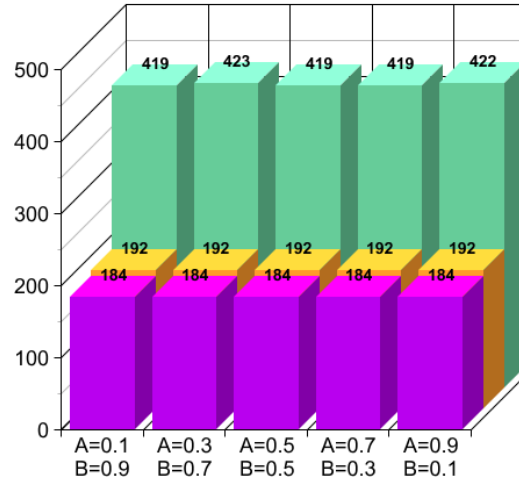
- OF0
- HC+RE
- MRHOF

Scenario 6: isteresi - worst case

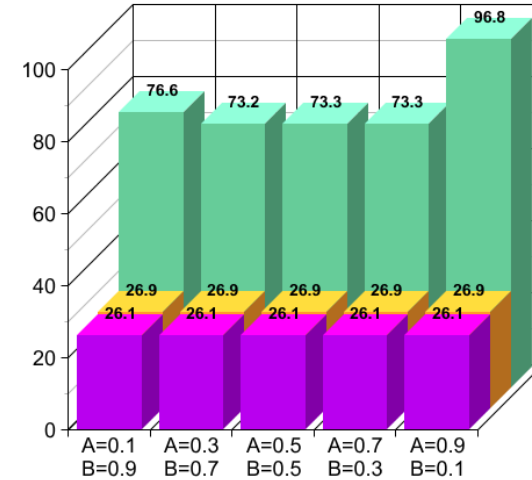
RPL LOSS (MAX)



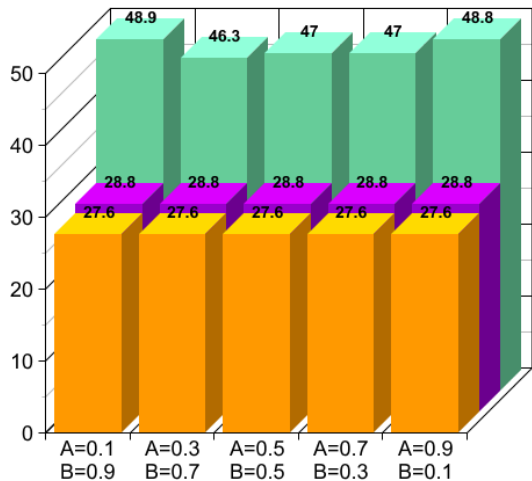
RPL RECEIVED (MAX)



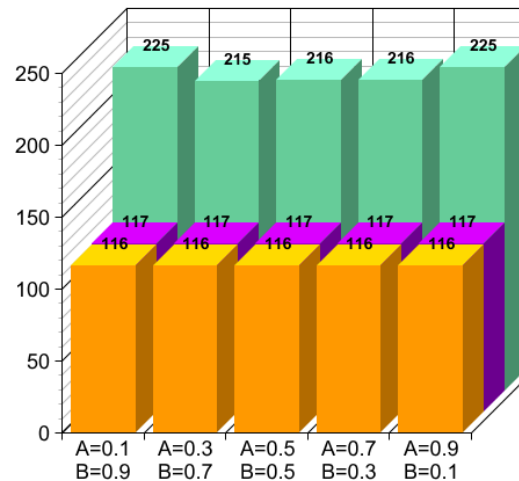
RPL SENDED (MAX)



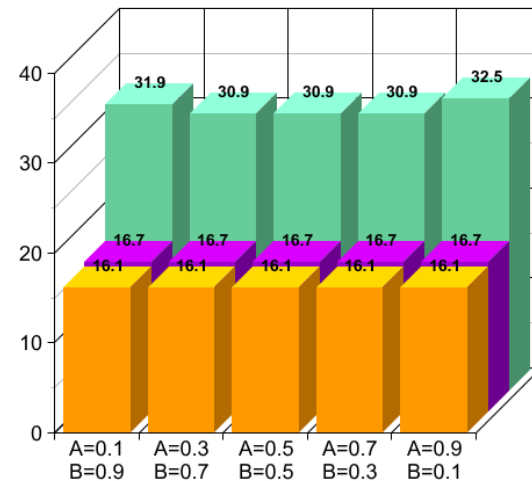
RPL LOSS (AVG)



RPL RECEIVED (AVG)



RPL SENDED (AVG)

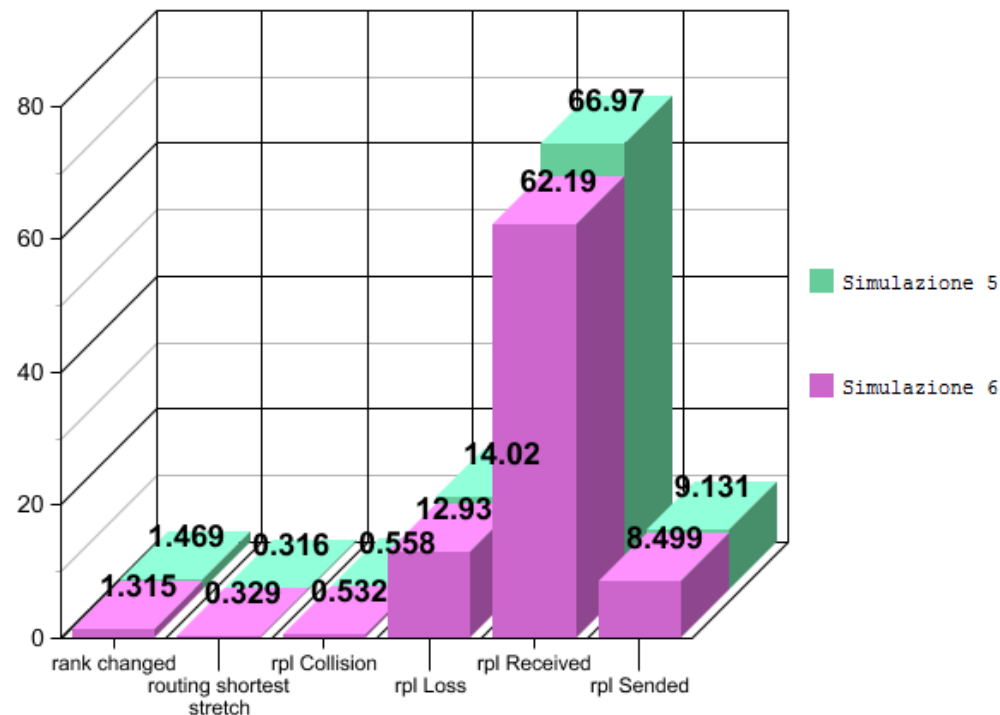


■ OF0
■ HC+RE
■ MRHOF

Scenario 6: isteresi – miglioramenti ottenuti

- Scenario 5:
soglia 3%, batteria 100'000 nJ
- Scenario 6:
soglia 3% e isteresi, batteria 100'000 nJ

Confronto fra le simulazioni ($I = 7$, $K = 3$) ($A = 0.3$, $B = 0.7$)



Scenario 6:

isteresi - conclusioni




- Si notano differenze comportamentali tra le diverse coppie (α , β)
- Per le coppie (0.1 , 0.9) e (0.3 , 0.7) si evidenzia un miglioramento rispetto MRHOF da un punto di vista del consumo energetico
- Risultati molto paragonabili con MRHOF ed OF0 per le restanti coppie
- *HC+RE con isteresi* si comporta molto bene (risultati quasi identici) sia con batteria da 500'000 nJ che da 100'000 nJ

Scenario 6:

isteresi - conclusioni

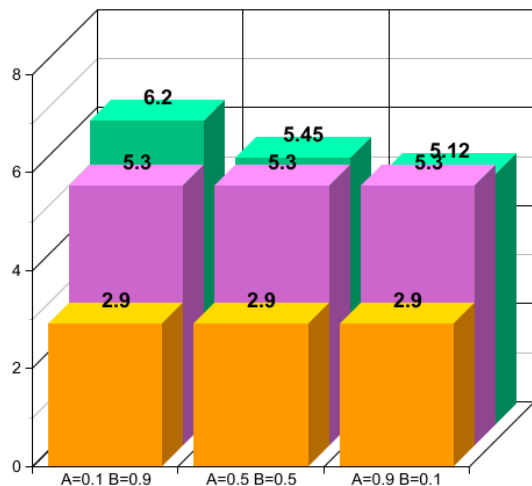
- Quando i nodi si scaricano HC+RE continua a funzionare bene
- Con entrambe le batterie (500'000 nJ e 100'000 nJ) i risultati sono soddisfacenti
- **Prossimo step** → Scenario con messaggi MAC
 - Verranno inviati un numero di messaggi molto maggiore
 - Comportamento più realistico nella scarica dei nodi

Scenario 7: messaggi MAC – parametri

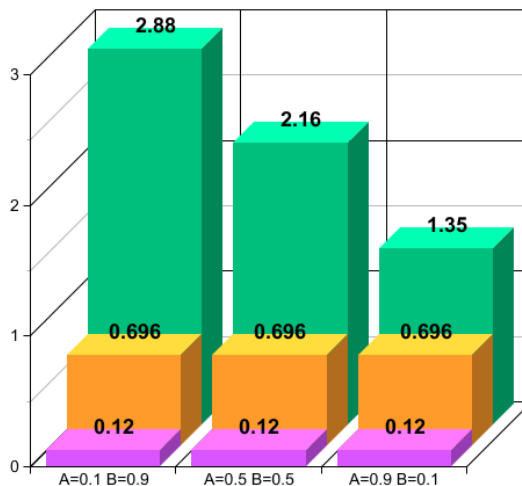
- Parametri simulazione
 - ($l=5$, $K=7$) , ($l=7$, $K=3$)
 - Parent_set = 1
 - Reset_time = 1035
 - Reset_type = true
 - OF_type = ENERGY, MRHOF, OF0 
- Soglia: 3%
- Isteresi
- Valori dei pesi 
 - $\alpha = 0.1, 0.5, 0.9$
 - $\beta = 0.9, 0.5, 0.1$
- Numero di run = 20
- Capacità batteria = 20'000'000 nJ 

Scenario 7: messaggi MAC – best case

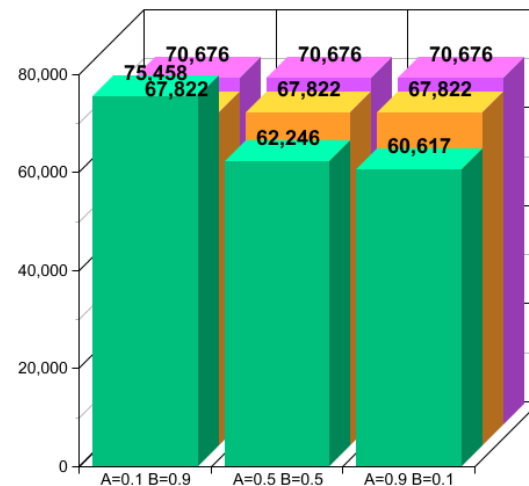
RANK CHANGED (MAX)



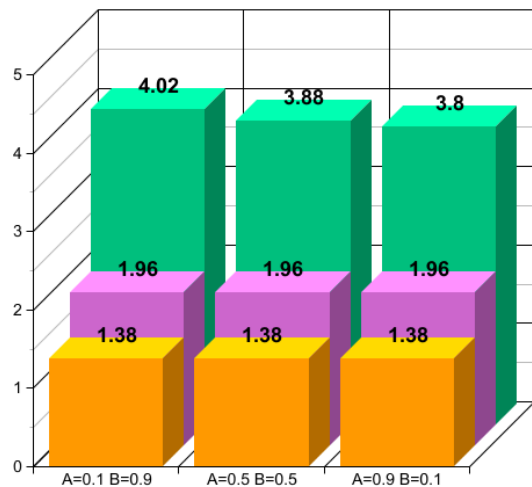
ROUTING SHORTEST STRETCH (MAX)



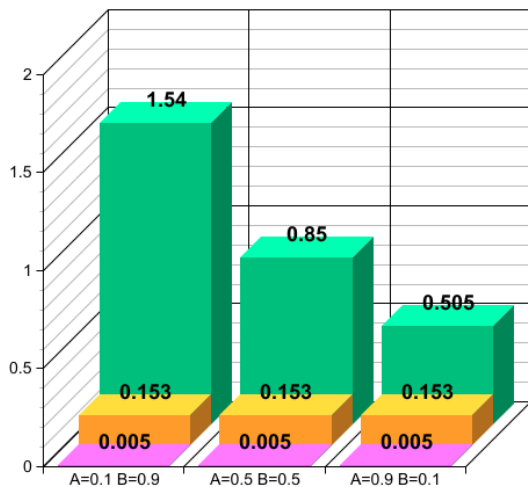
RPL COLLISION (MAX)



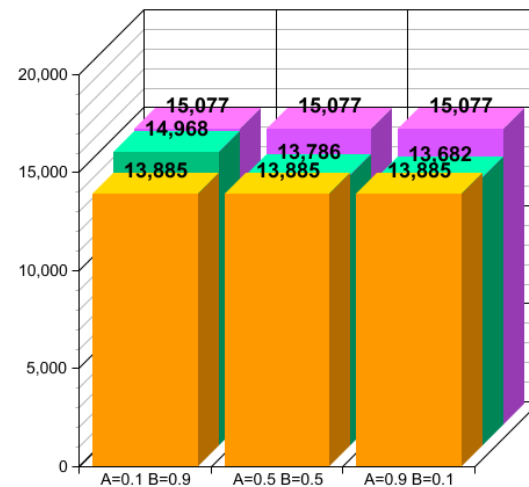
RANK CHANGED (AVG)



ROUTING SHORTEST STRETCH (AVG)



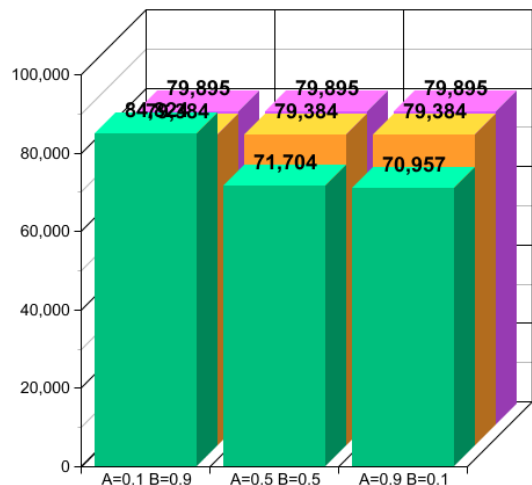
RPL COLLISION (AVG)



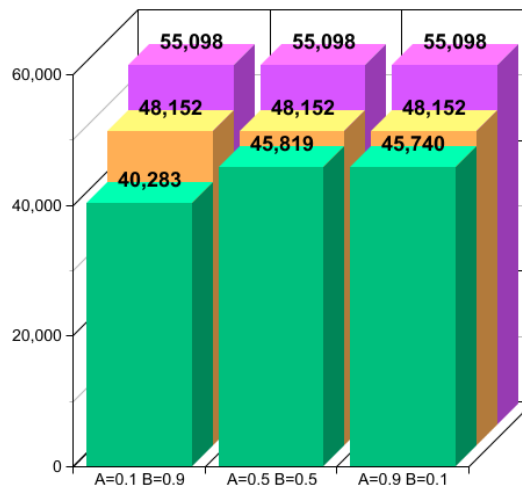
- OF0
- HC+RE
- MRHOF

Scenario 7: messaggi MAC – best case

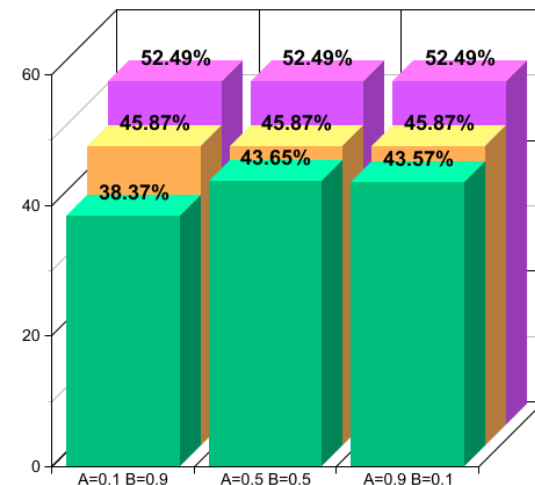
RPL LOSS (MAX)



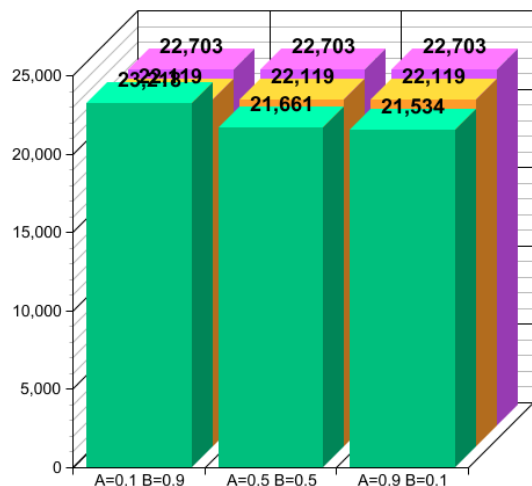
MESSAGE SENDED (MAX)



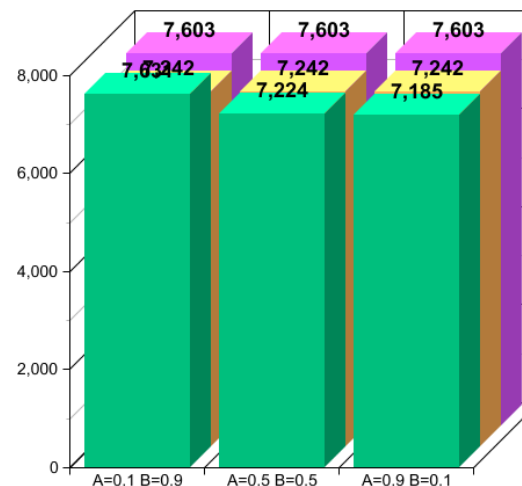
ENERGY CONSUMED (MAX)



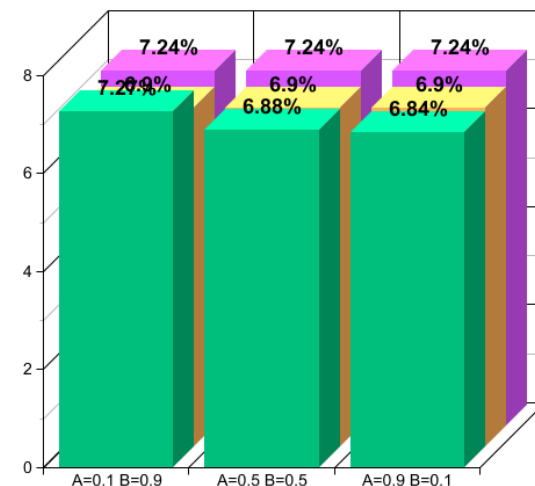
RPL LOSS (AVG)



MESSAGE SENDED (AVG)



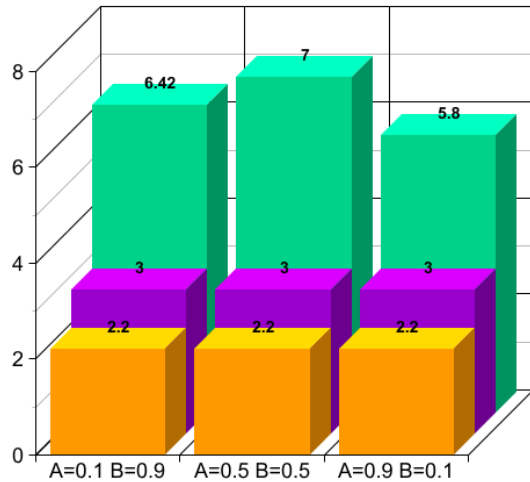
ENERGY CONSUMED (AVG)



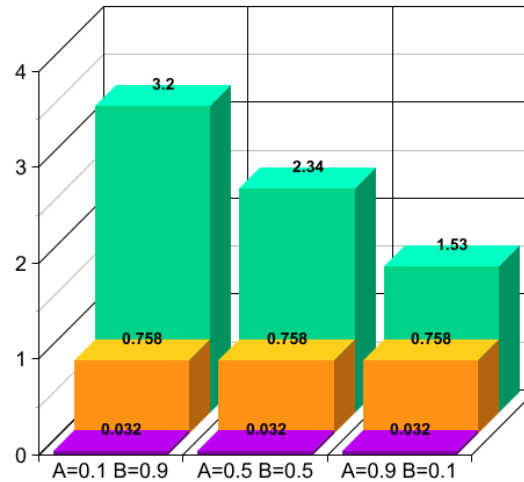
- OF0
- HC+RE
- MRHOF

Scenario 7: messaggi MAC – worst case

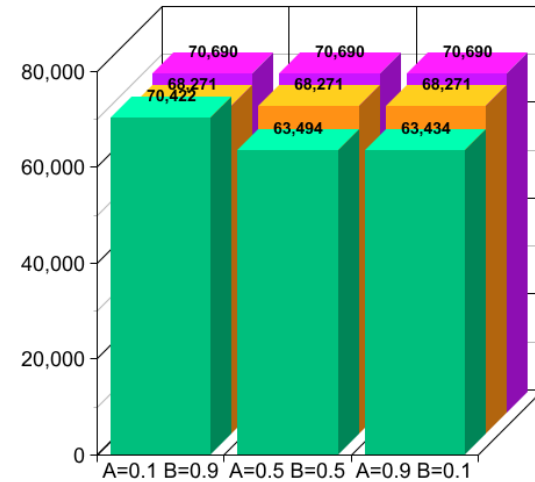
RANK CHANGED (MAX)



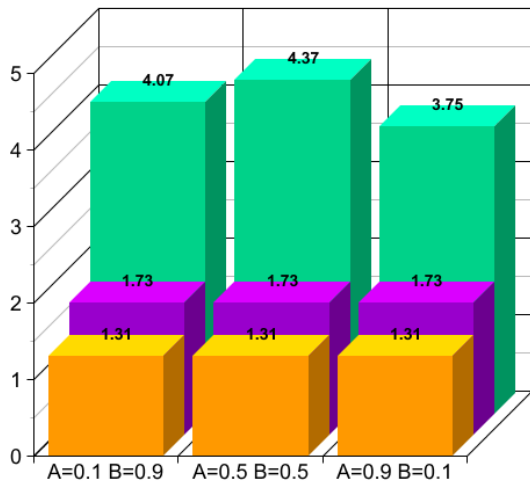
ROUTING SHORTEST STRETCH (MAX)



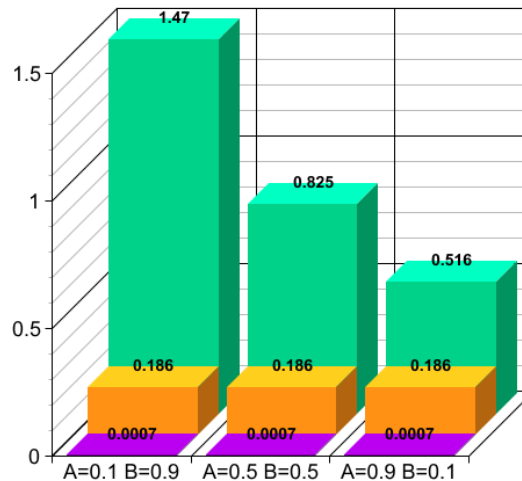
RPL COLLISION (MAX)



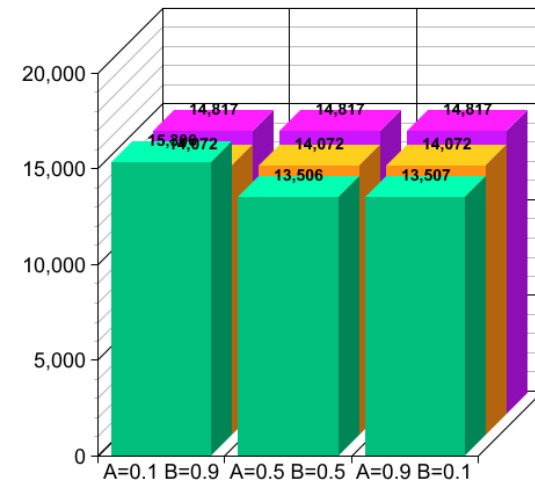
RANK CHANGED (AVG)



ROUTING SHORTEST STRETCH (AVG)



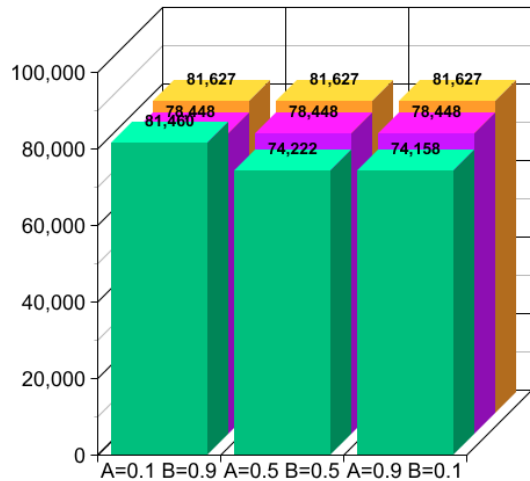
RPL COLLISION (AVG)



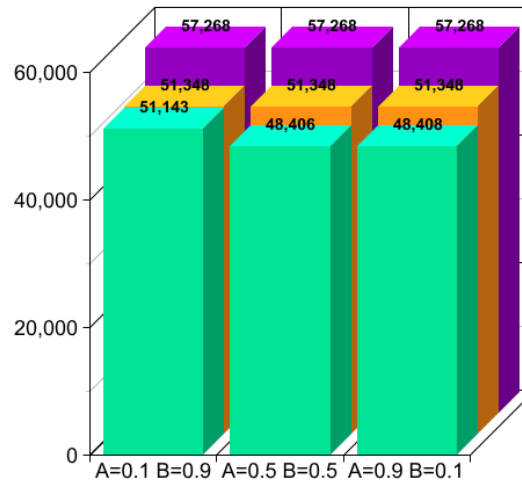
- OF0
- HC+RE
- MRHOF

Scenario 7: messaggi MAC – worst case

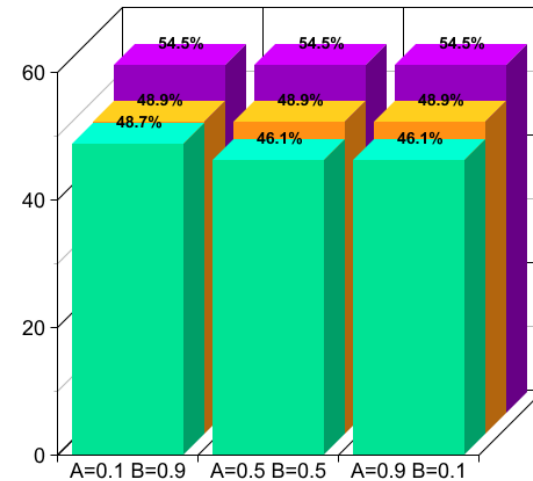
RPL LOSS (MAX)



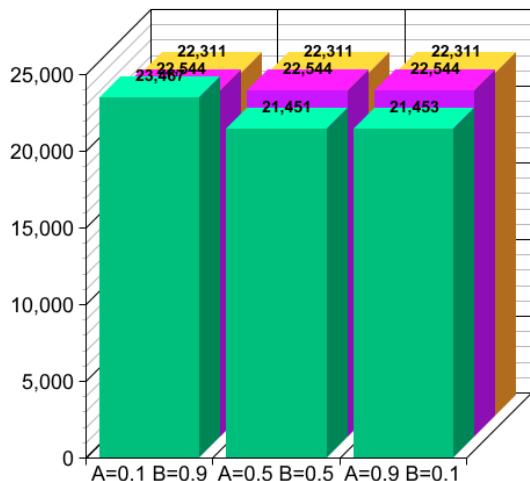
MESSAGE SENDED (MAX)



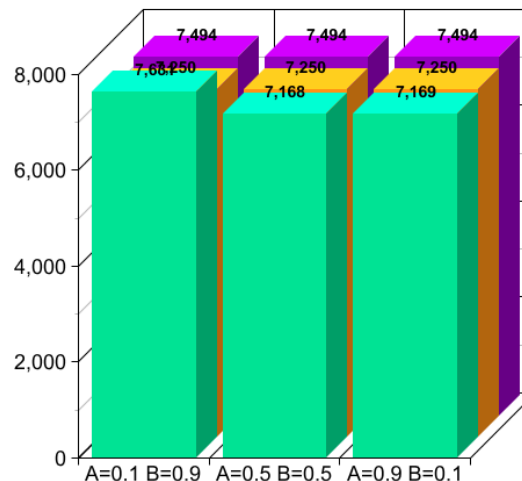
ENERGY CONSUMED (MAX)



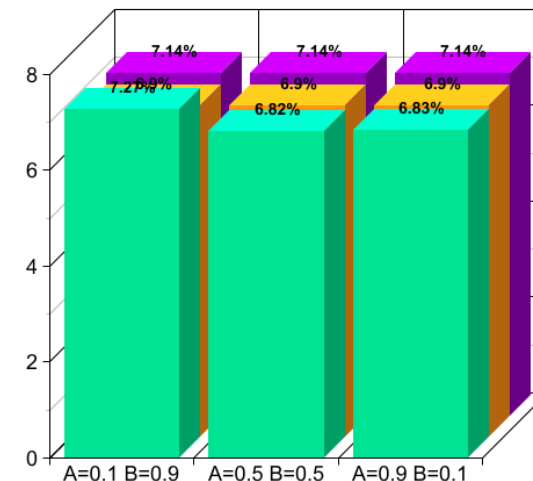
RPL LOSS (AVG)



MESSAGE SENDED (AVG)



ENERGY CONSUMED (AVG)



- OF0
- HC+RE
- MRHOF

Scenario 7:

messaggi MAC – conclusioni

- **Shortest Stretch**: peggioramento rispetto a MRHOF e OF0
 - prezzo da pagare per risparmiare energia
- **Energy**: valori medi paragonabili a MRHOF e OF0 mentre quelli massimi sono inferiori
 - HC+RE implementa una politica di bilanciamento dell'energia, scaricando i nodi in modo più uniforme



FINE

Grazie dell'attenzione