Routing in a Cyclic MobiSpace

SS 2008
Seminar: Computer Networks and Telematics
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Supervisor: Chia Ching Ooi and Faisal Aslam

Jonas Lipps

Agenda

- Problem / Motivation
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- Probabilistic Graph Models
  - Expected Minimum Delay (EMD)
  - Cyclic MobiSpace
  - Probabilistic time-space graph
  - Probabilistic state-space graph
  - Markov Decision Process (MDP)
  - Efficient approach for EMDs
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  - Markov Decision Process (MDP)
  - Efficient approach for EMDs
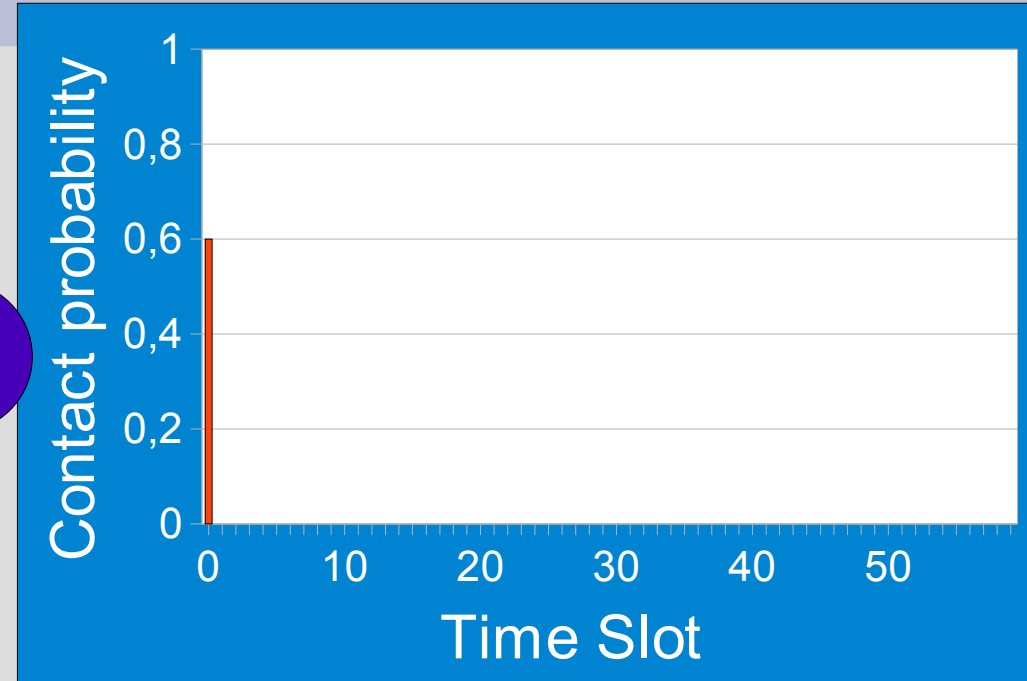- Simulation
  - Different protocols
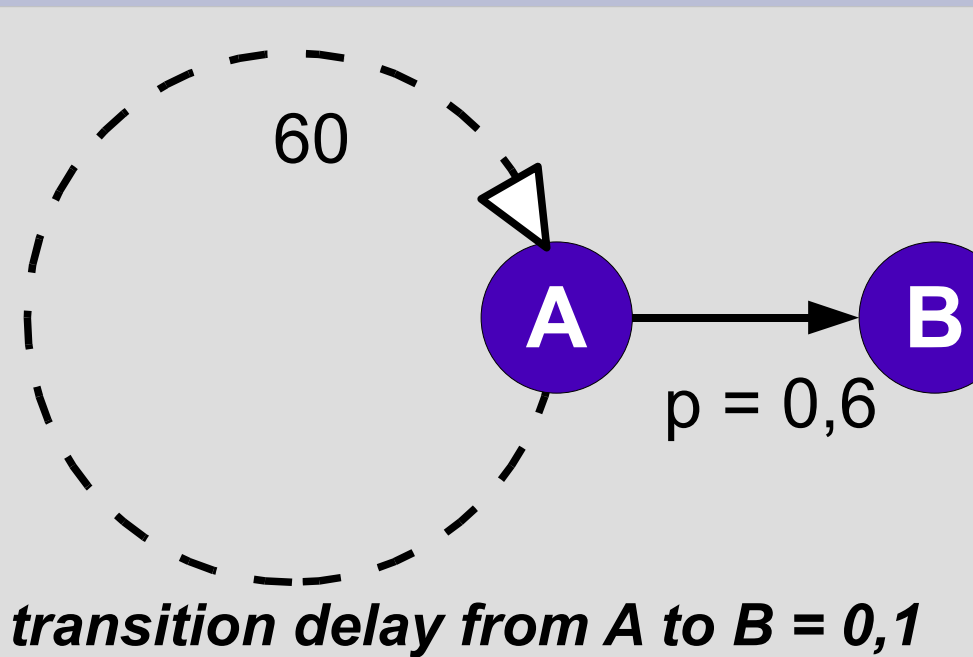 - Different traces

What is a Cyclic MobiSpace

- Mobispace
  - Euclidean space (or other higher dimensional space)
  - Nodes can be either static or mobil
  - Nodes can communicate within each other's transmission range

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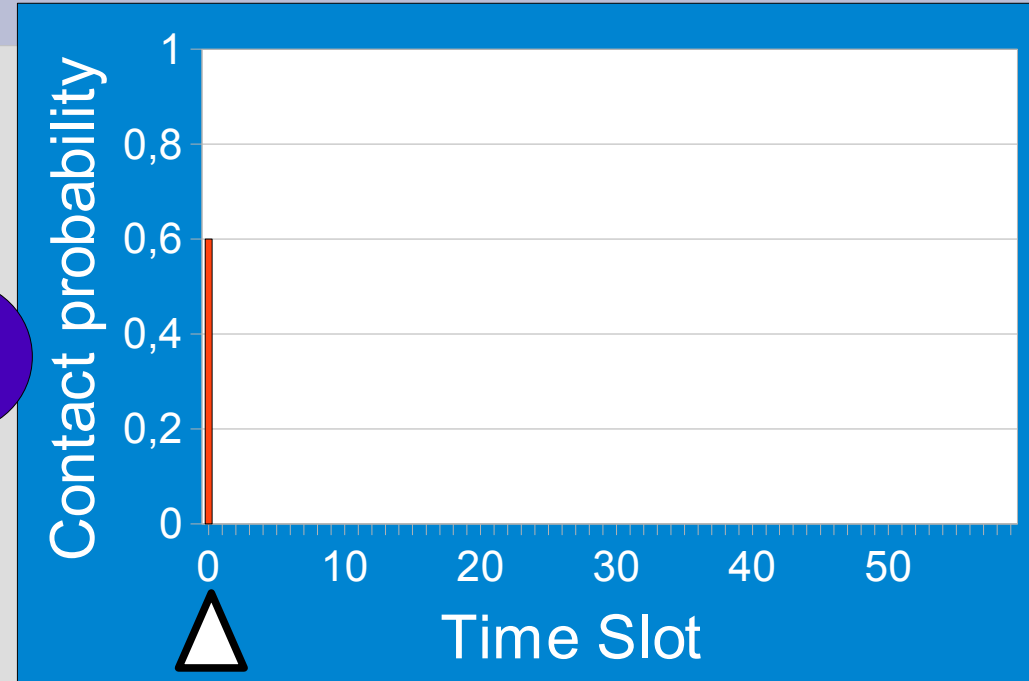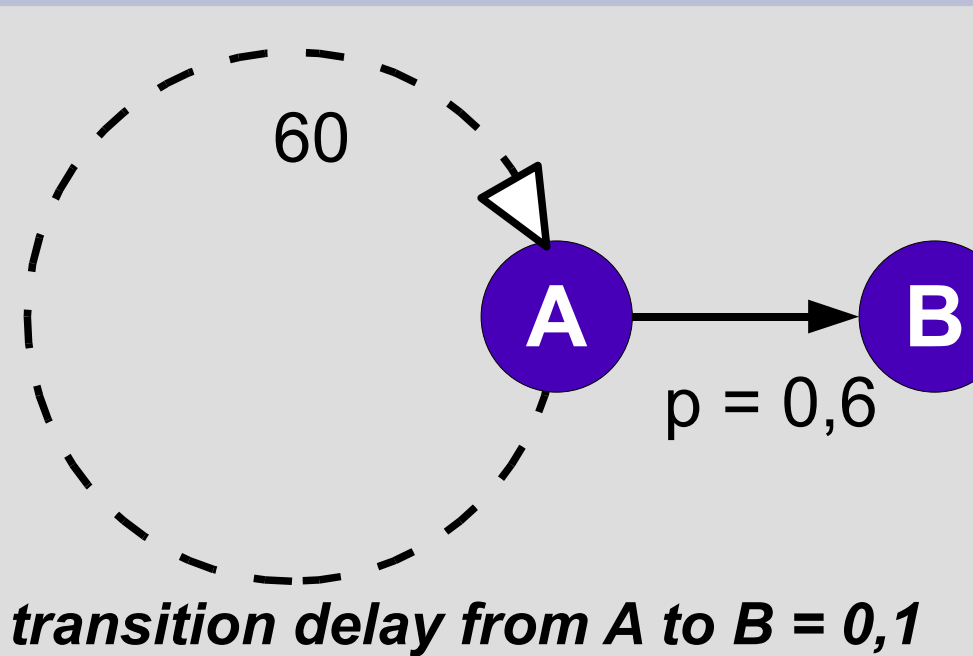
- Cyclic MobiSpace
  - A MobiSpace + mobility is cyclic

Routing in delay tolerant Networks (DNTs)

- **Problem**
  - Frequent network partitioning
    - High mobility
    - Low density
    - Short radio range
    - Interference
    - Obstruction
    - etc.
- **Goal**
  - Find routes with:
    - ↑ High delivery rates
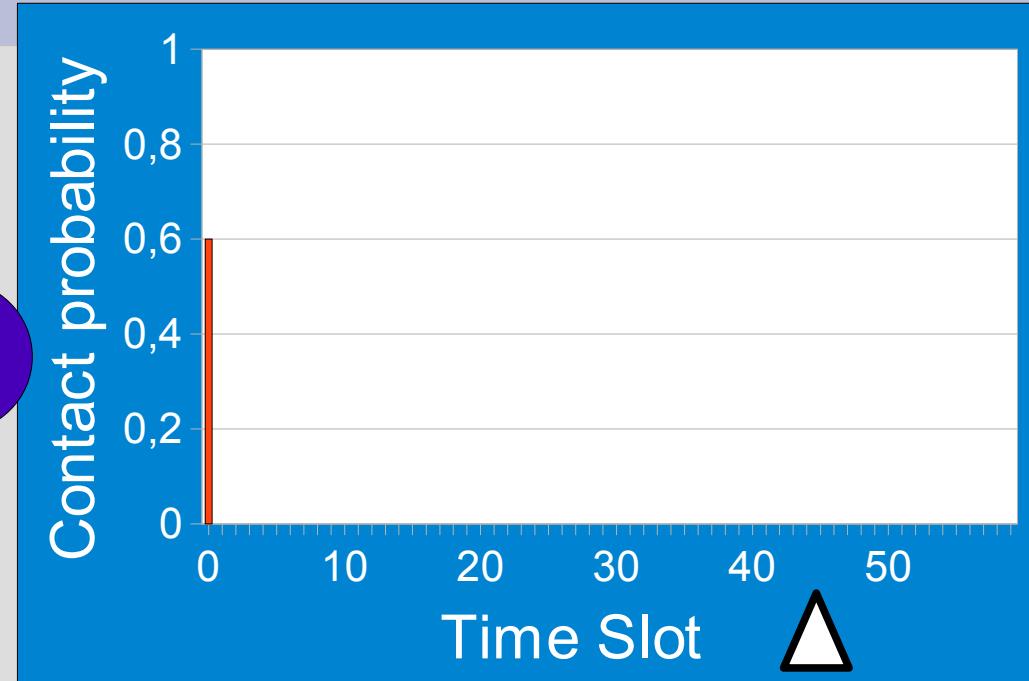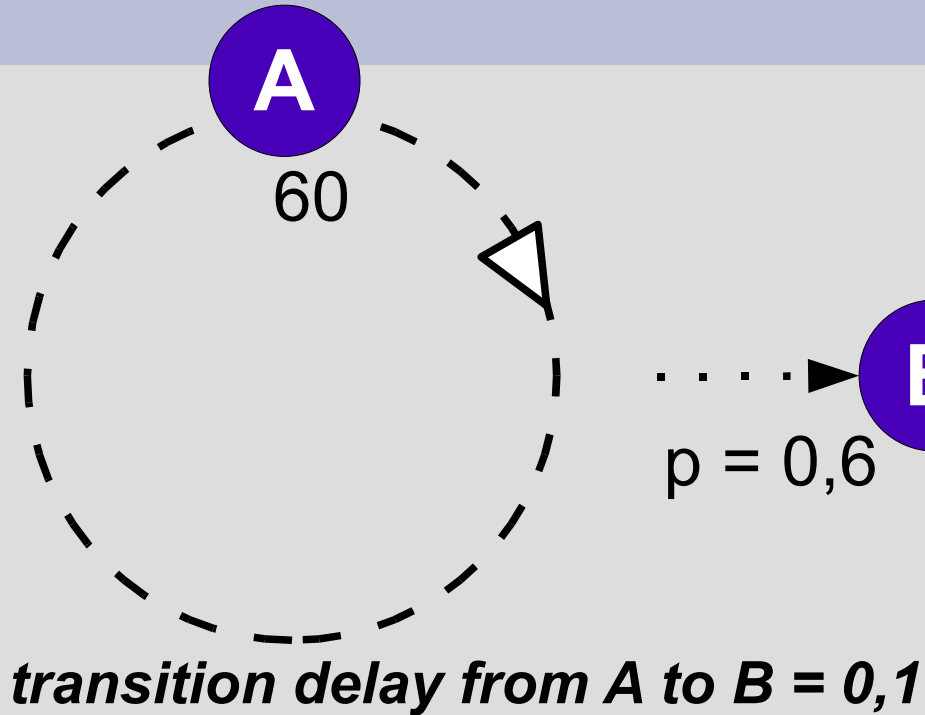   - ↕ Low end to end delay

Expected Minimum Delay (1)
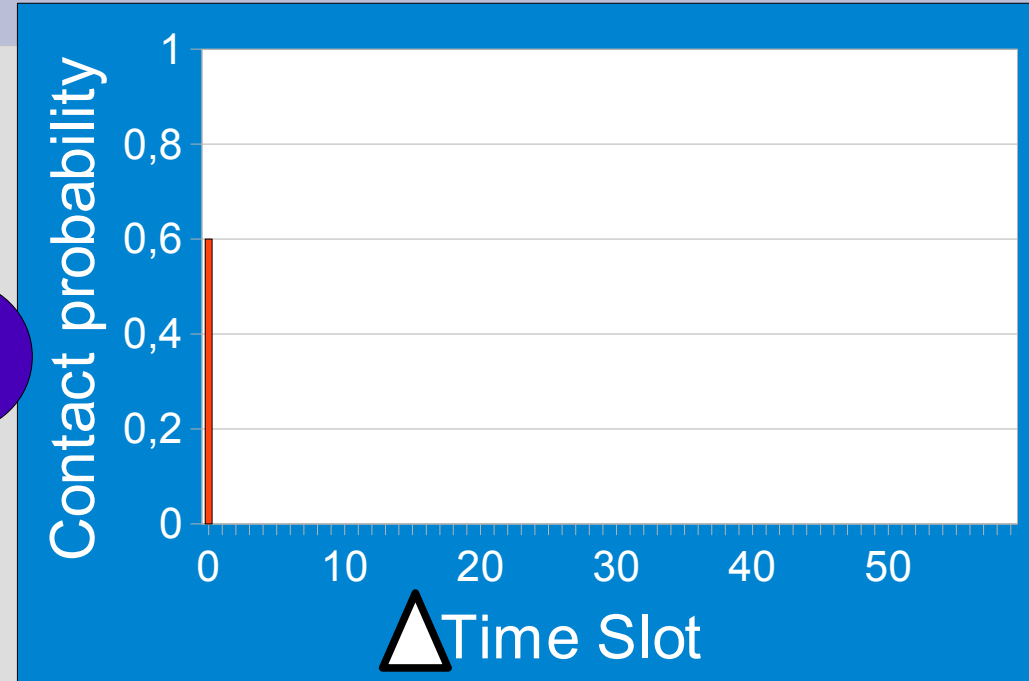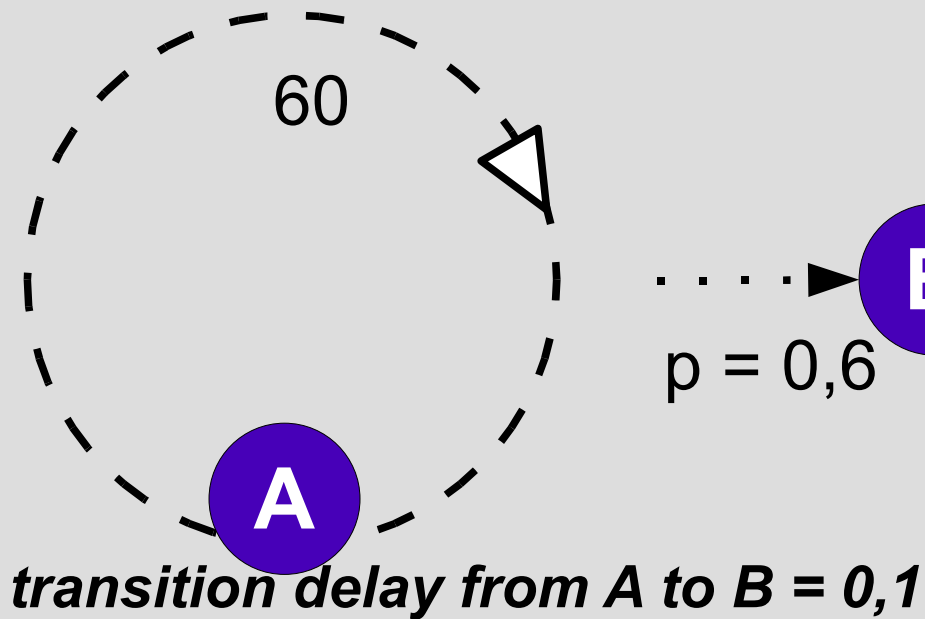
60

A → **B**

p = 0,6

transition delay from A to B = 0,1

Contact probability

1

0,8

0,6

0,4

0,2

0

0   10   20   30   40   50

Time Slot

Expected Minimum Delay (1)

transition delay from A to B = 0,1

Expected Minimum Delay (1)

60

B

p = 0,6

A

transition delay from A to B = 0,1

Contact probability

1

0,8

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0   10   20   30   40   50

Time Slot

Expected Minimum Delay (1)

transition delay from A to B = 0,1

Expected Minimum Delay (1)

A

60

B

p = 0,6

transition delay from A to B = 0,1

Contact probability

1

0,8

0,6

0,4

0,2

0

0   10   20   30   40   50

Time Slot

Expected Minimum Delay (1)

60

A → B

p = 0,6

transition delay from A to B = 0,1

Expected Minimum Delay (2)

transition delay from A to B = 0,1
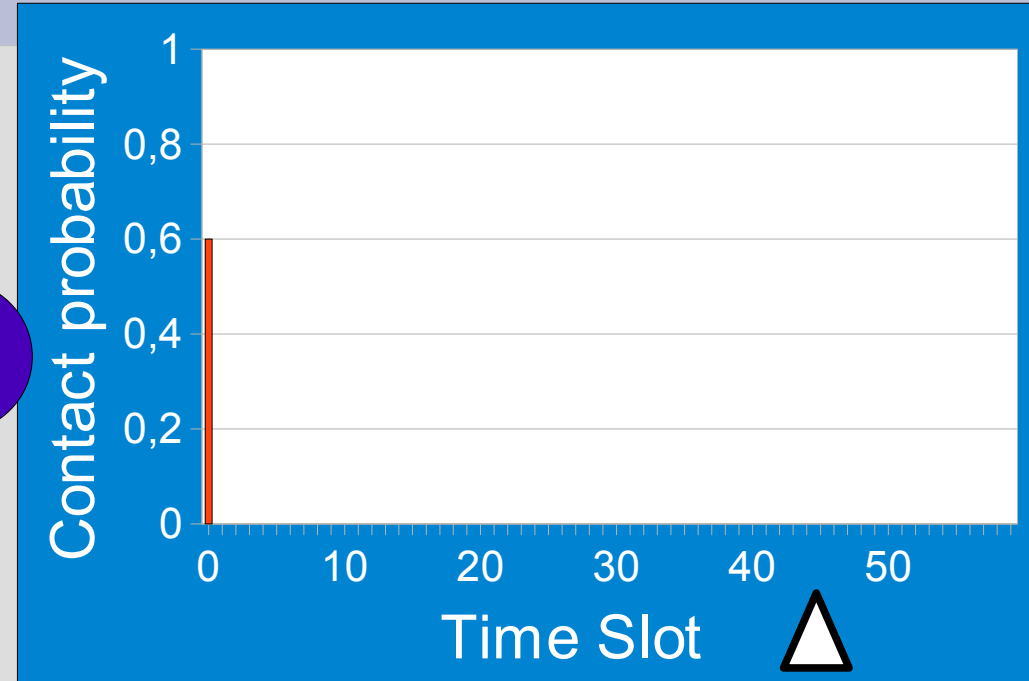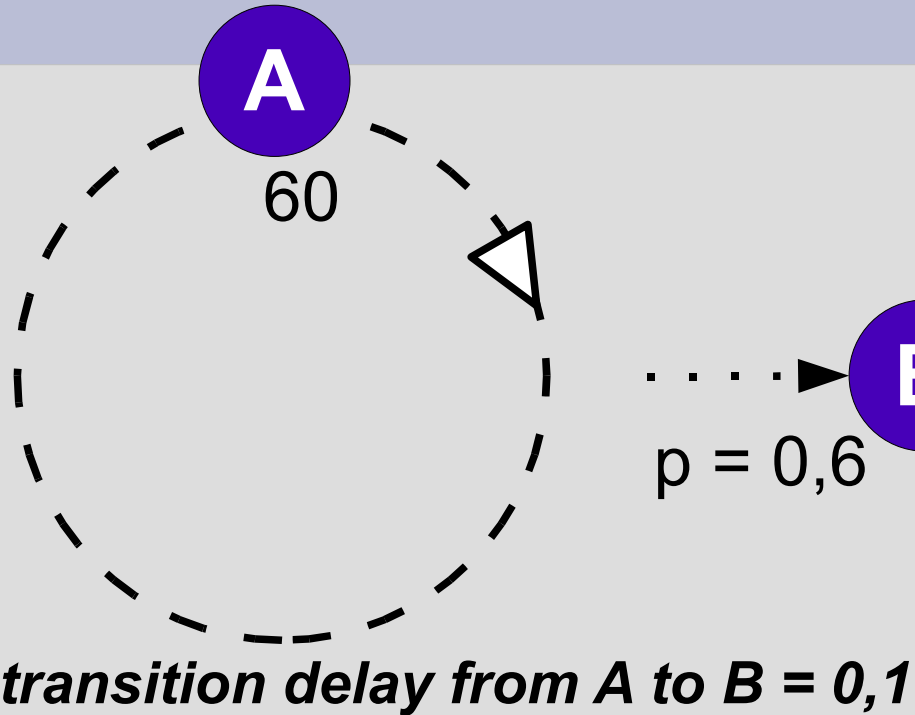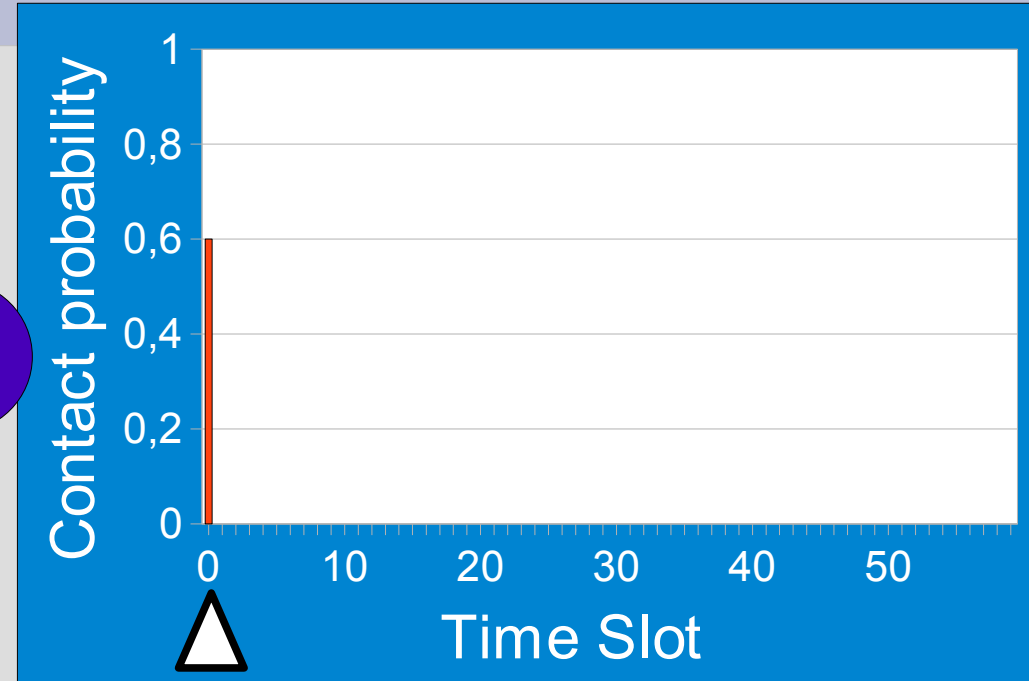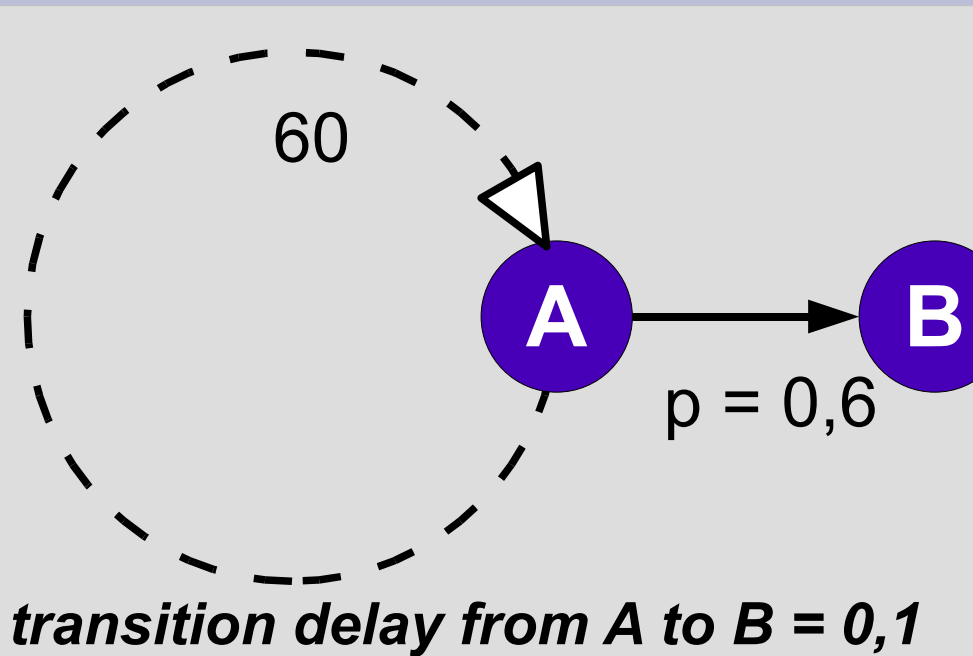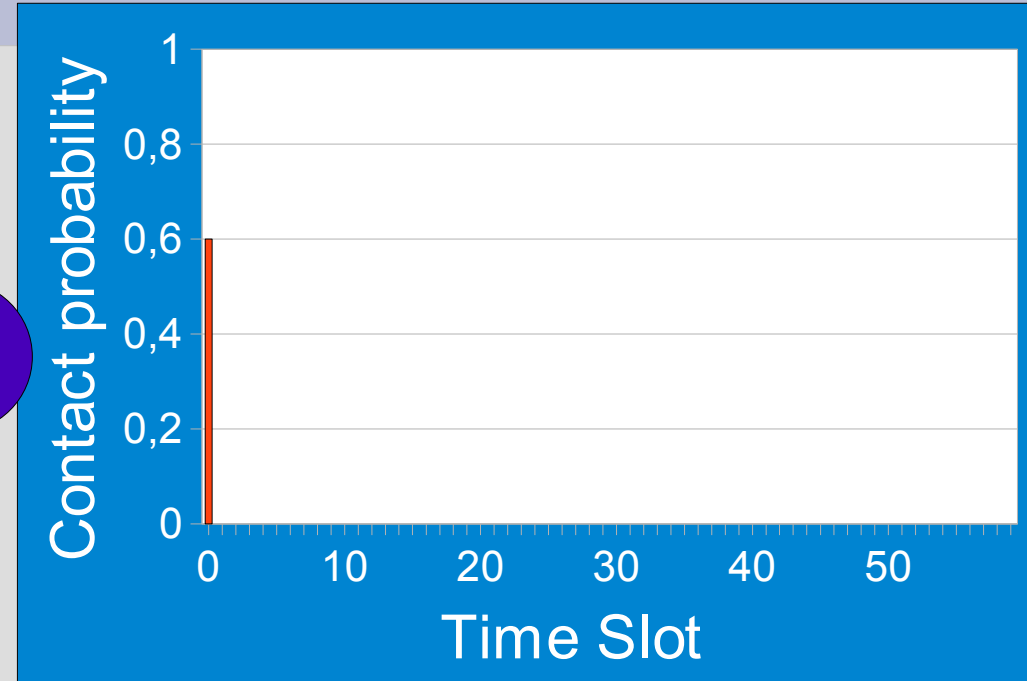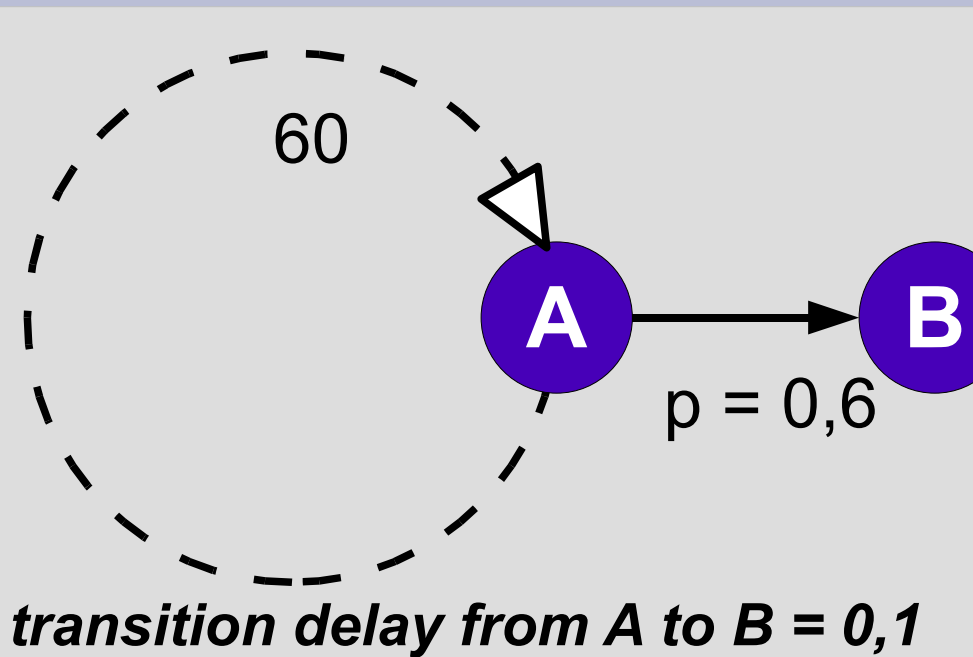
Question: What is the EMD D_0 ?

Expected Minimum Delay (2)

60

A → **B**

p = 0,6

transition delay from A to B = 0,1
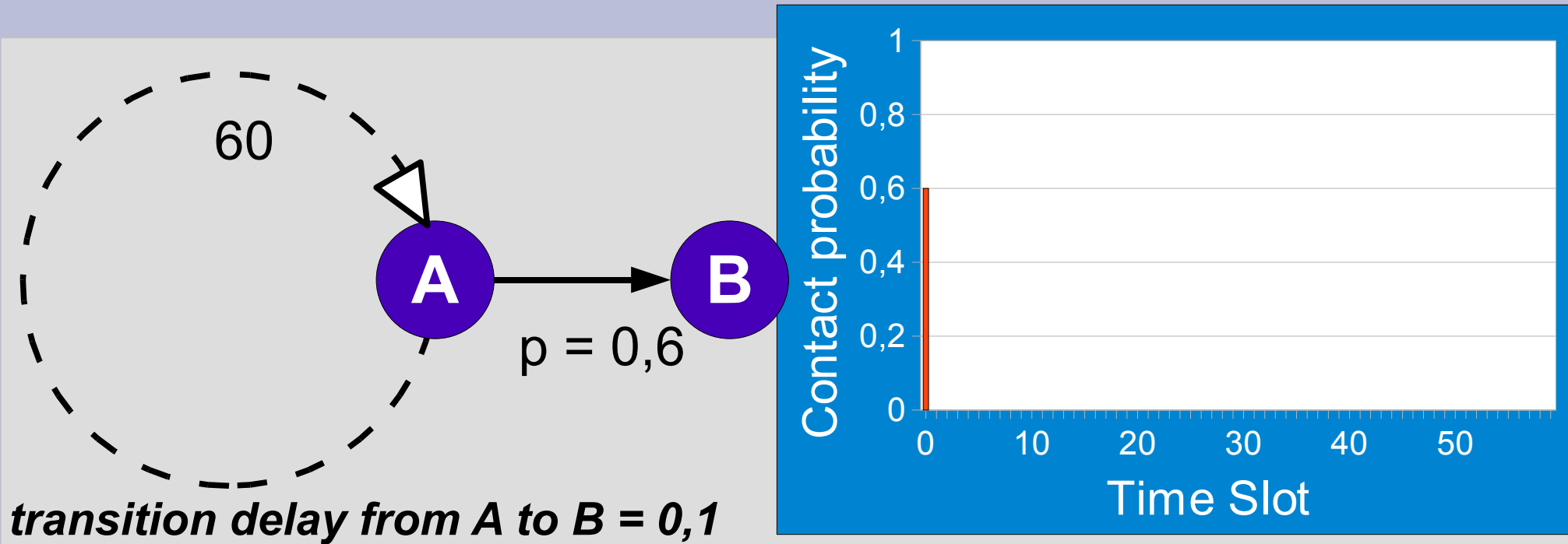
Question: What is the EMD D_0 ?
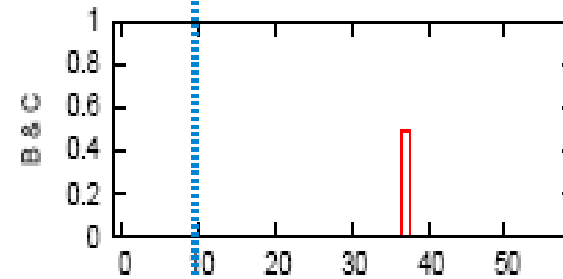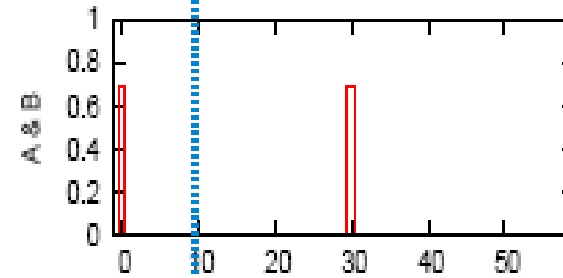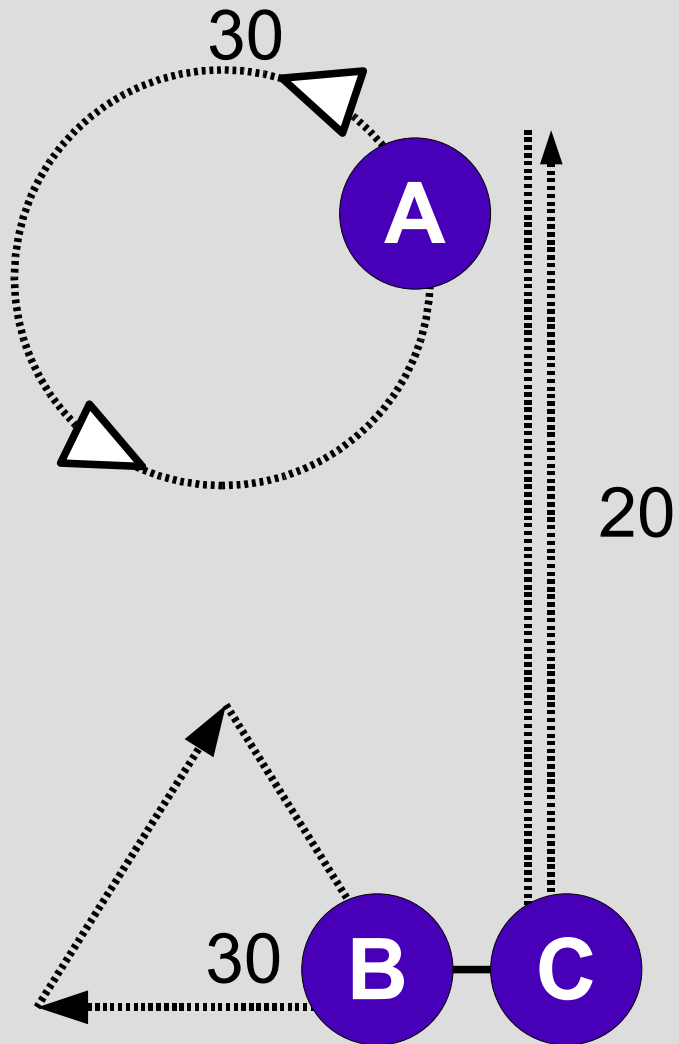
Answer: $D_0 = 0.6 * 0.1 + 0.4 * (60 + D_0)$

Expected Minimum Delay (2)

60

A → **B**

p = 0,6

transition delay from A to B = 0,1
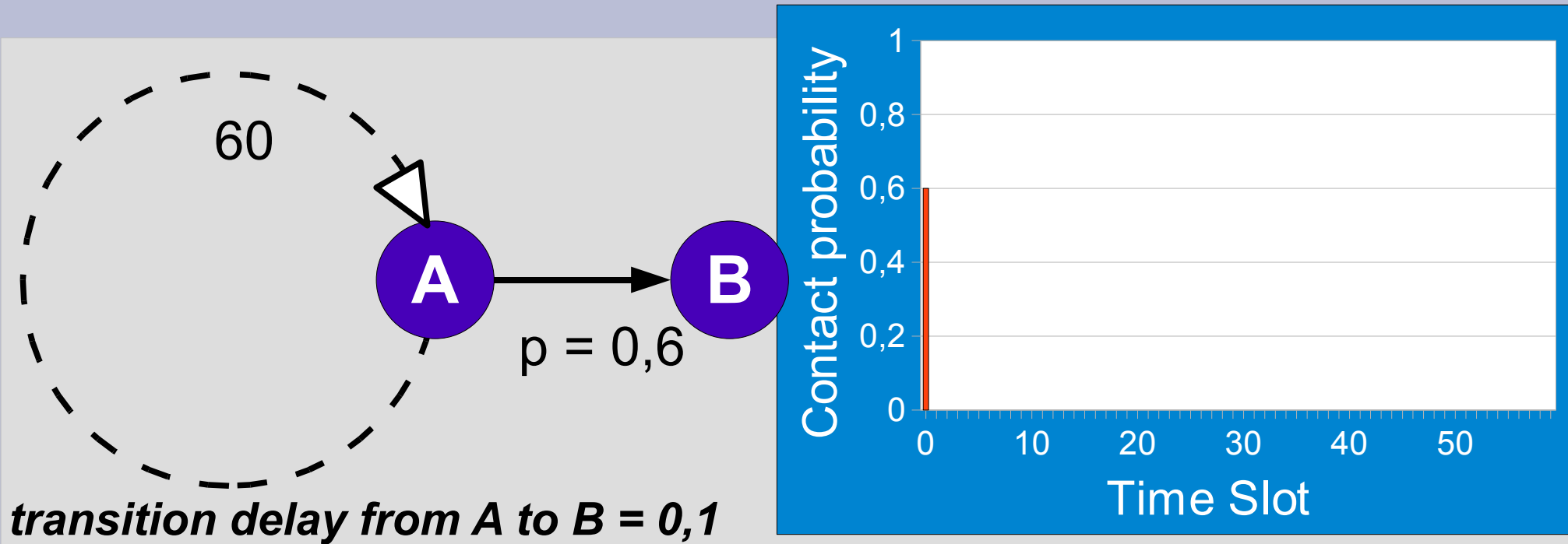
Question: What is the EMD D_0 ?

Answer: $D_0 = 0.6 * 0.1 + 0.4 * (60 + D_0)$

$D_t = D_0 + (60 - t \bmod 60) \bmod 60$

Cyclic MobiSpace
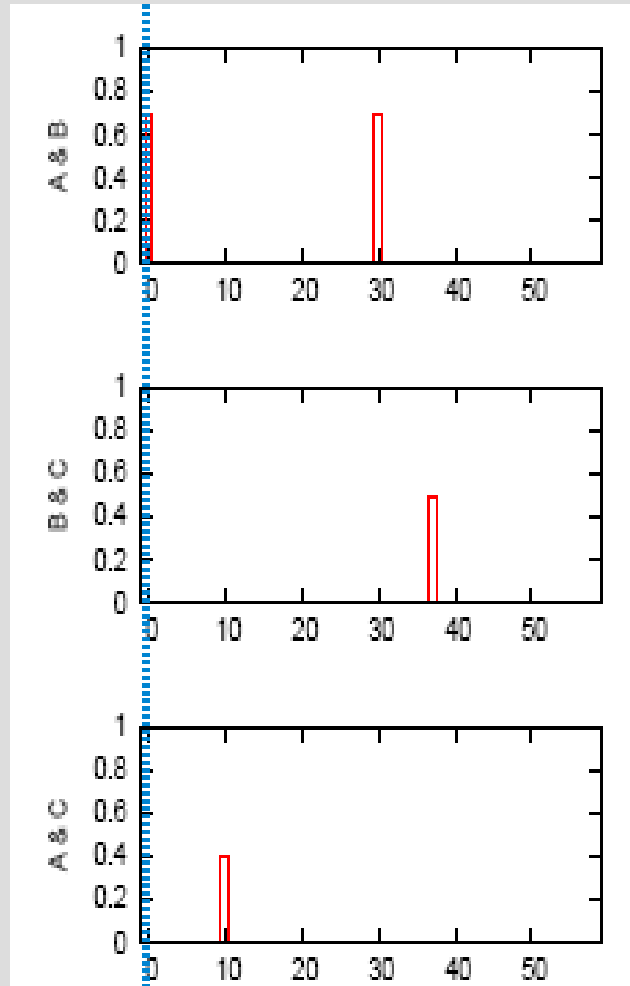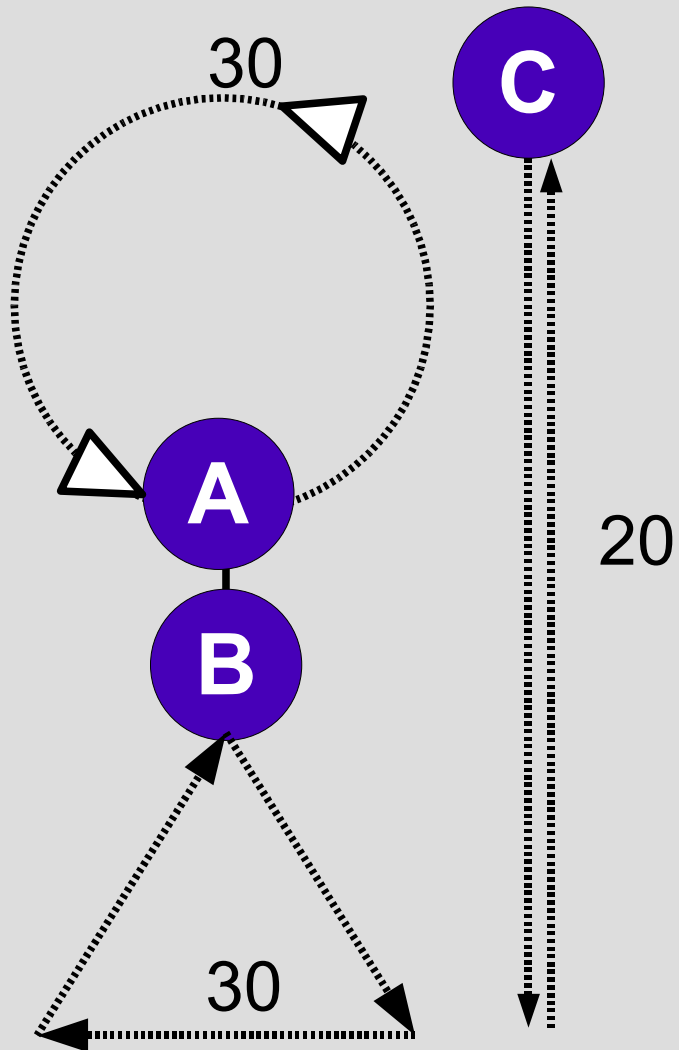
Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu
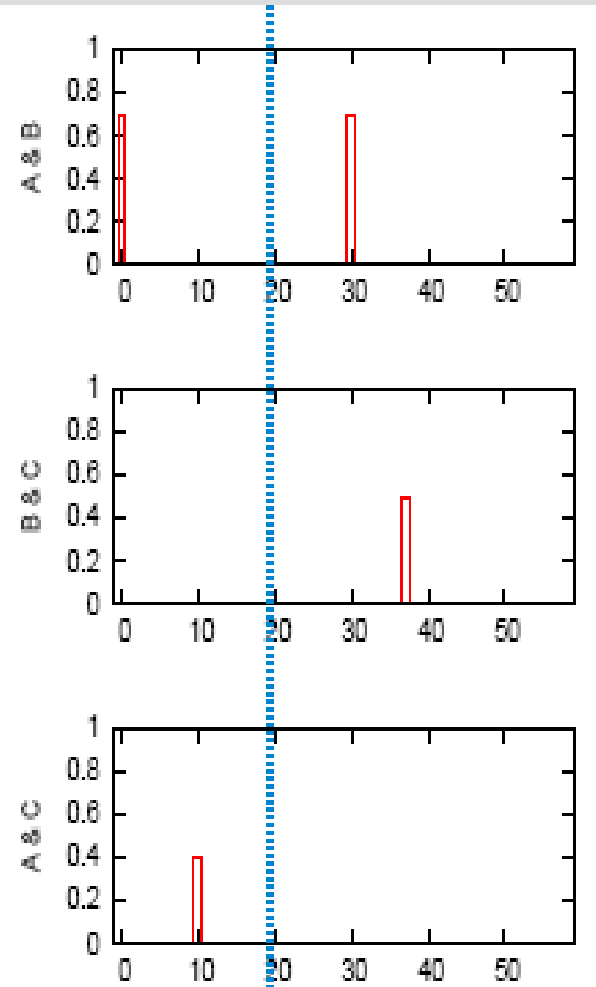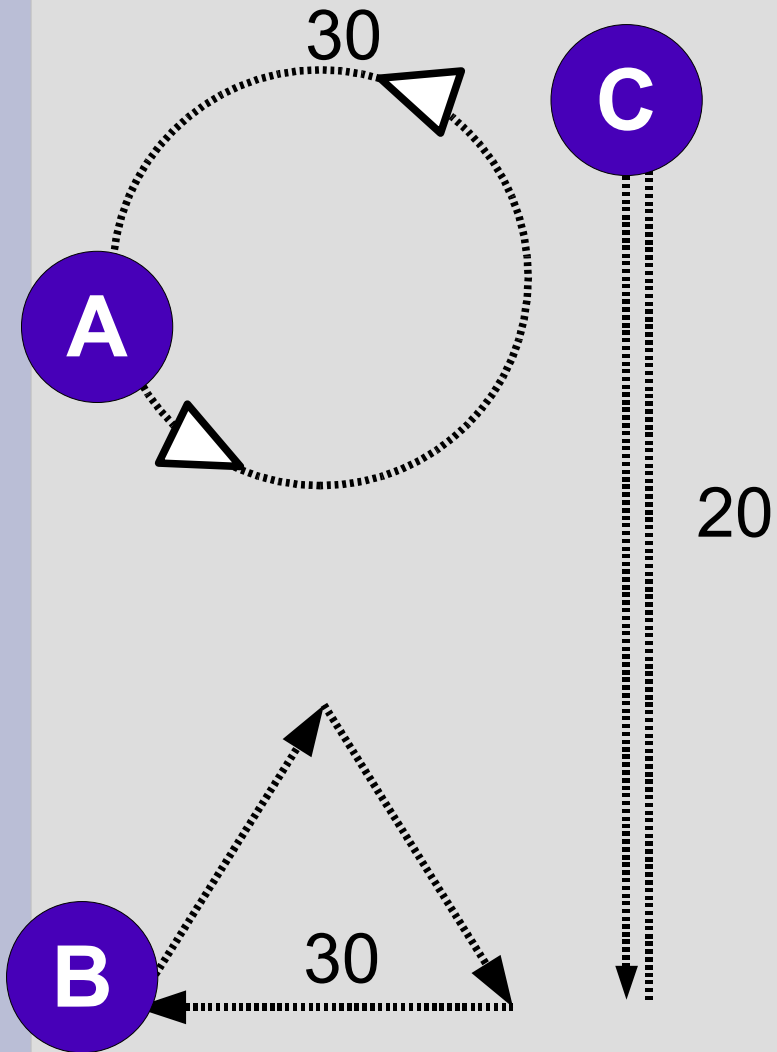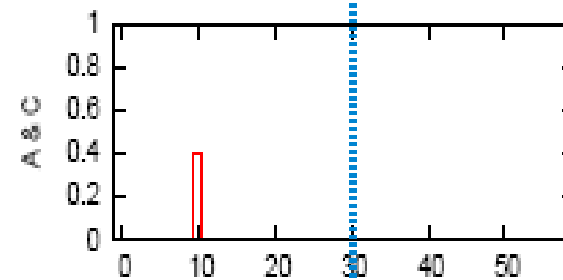
Cyclic MobiSpace

30

A

20

30   B — C
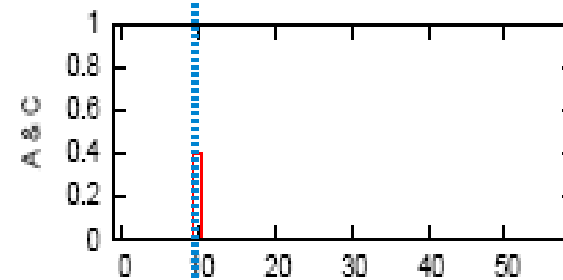
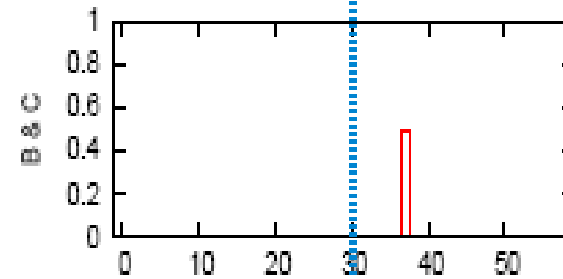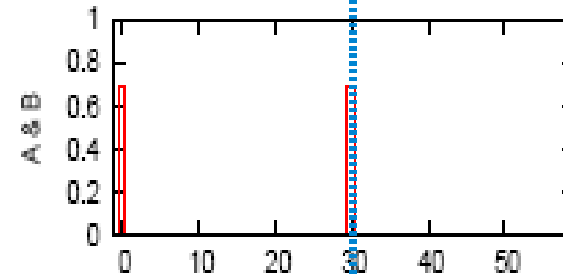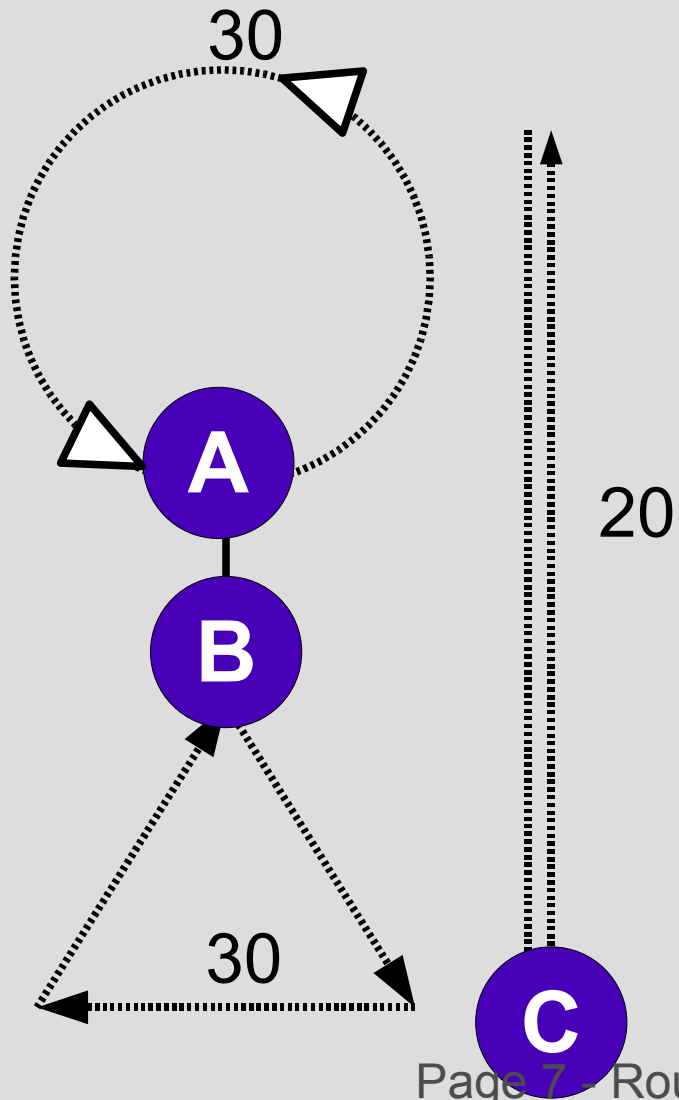*Source: Routing in a Cyclic MobiSpace*
Cong Liu and Jie Wu

Cyclic MobiSpace

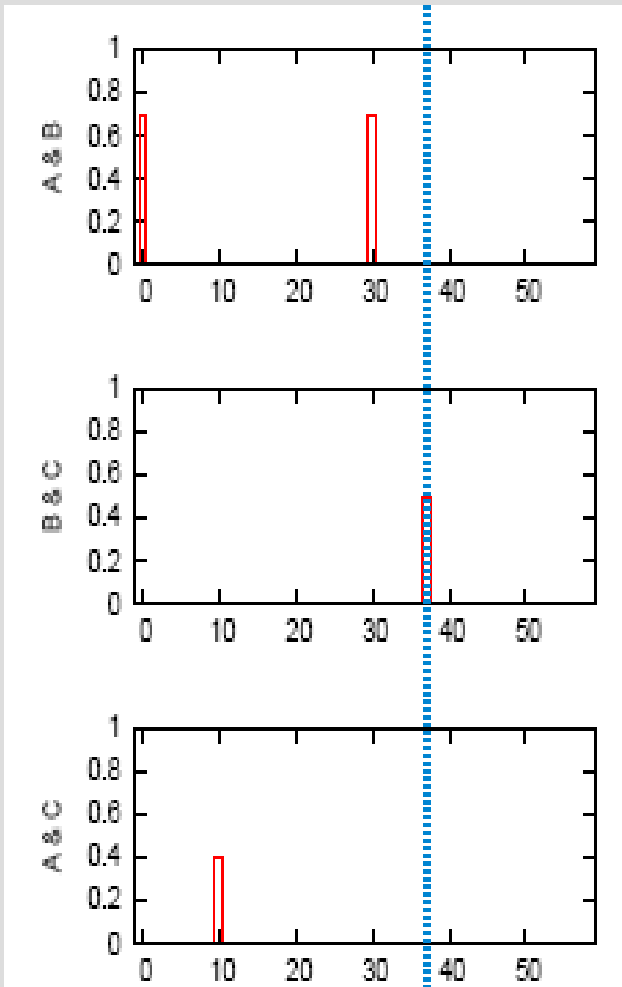*Source: Routing in a Cyclic MobiSpace*
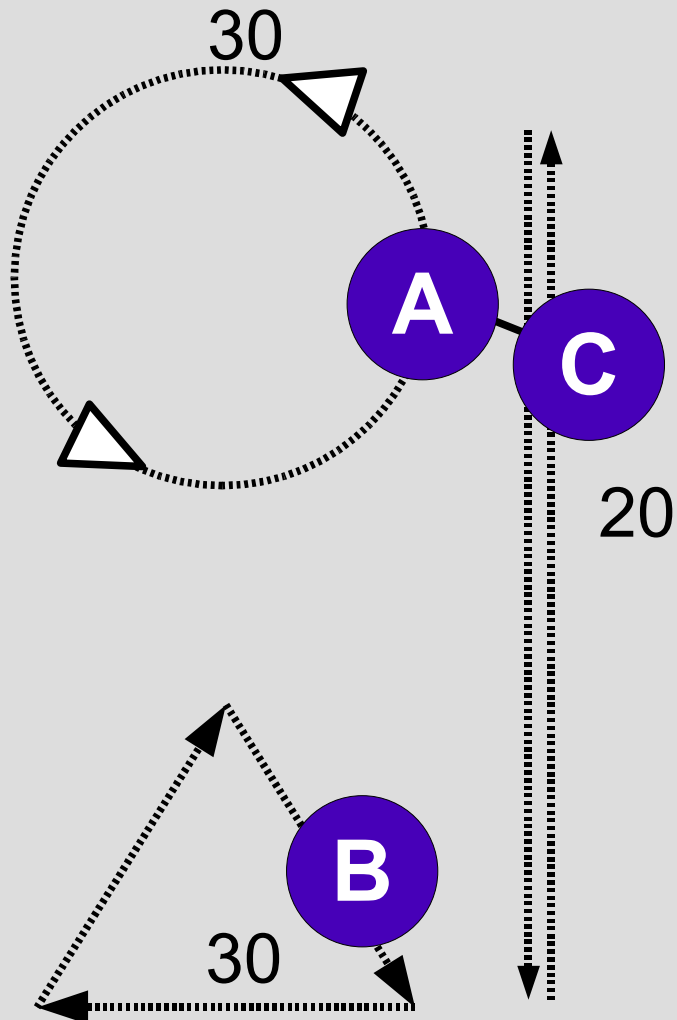*Cong Liu and Jie Wu*

Cyclic MobiSpace

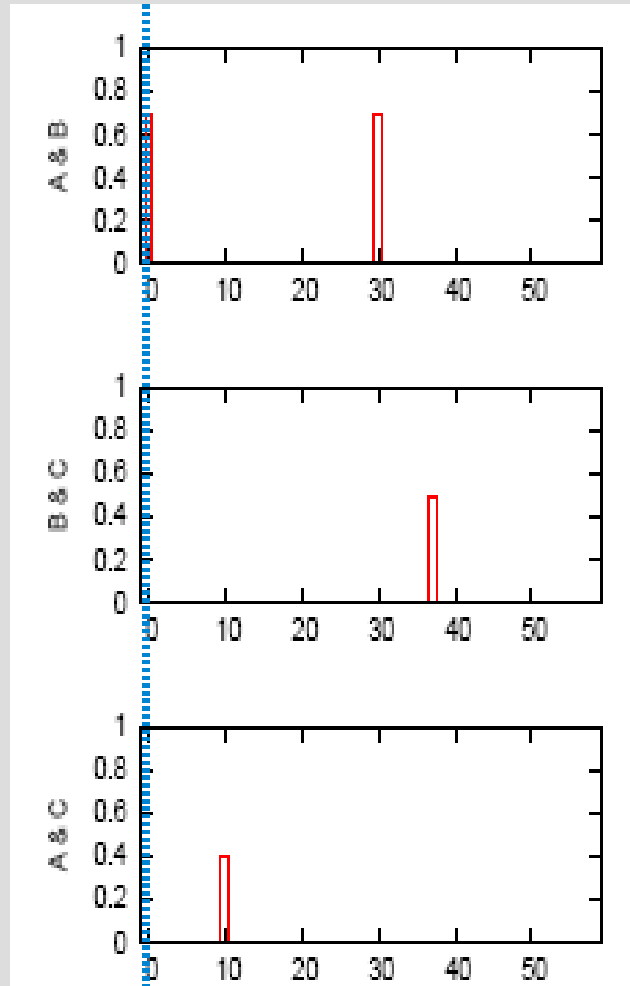
Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

Cyclic MobisSpace

Source: Routing in a Cyclic MobiSpace
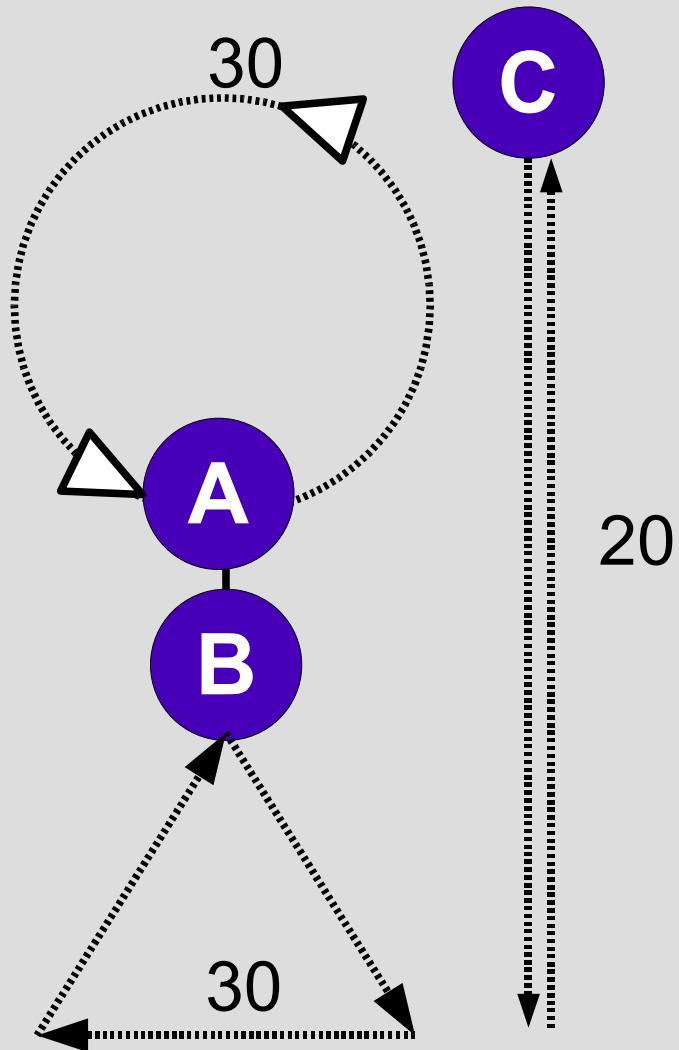*Cong Liu and Jie Wu*

Cyclic MobiSpace

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

Probabilistic time-space graph

Formal Defintion of *a probabilistic time-space graph:*
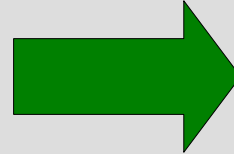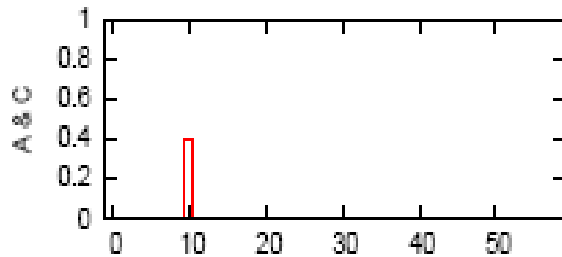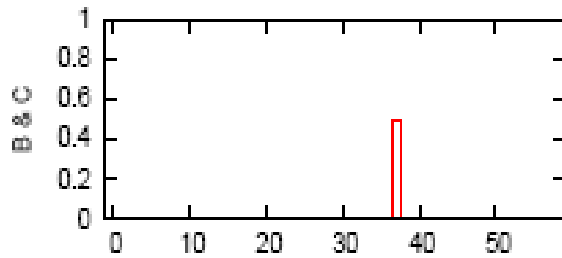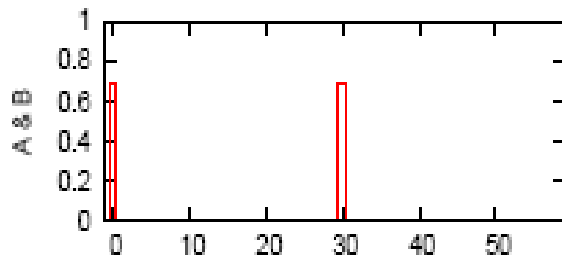
G = (V,E,T)
V is the set of nodes
E is the set of edges between nodes
T is the common motion Cycle (60 in our example)

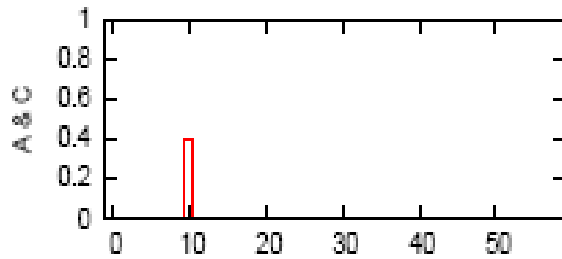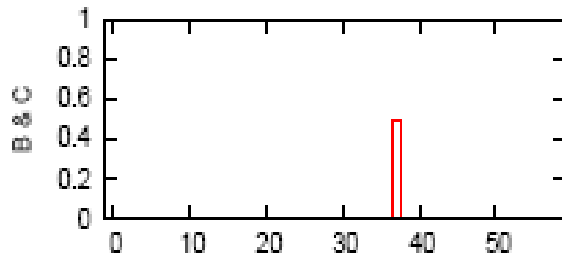# Cyclic MobiSpace ->Probabilistic time-space graph

Cyclic MobiSpace

Probabilistic time-space graph G

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

Cyclic MobiSpace ->Probabilistic time-space graph

Cyclic MobiSpace

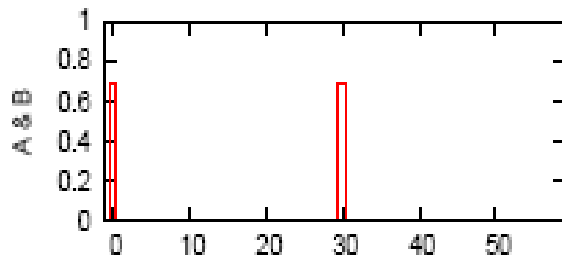*Probabilistic time-space graph G*

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

Cyclic MobiSpace ->Probabilistic time-space graph

Cyclic MobiSpace

Probabilistic time-space graph G

(0 , 0.7)

(30 , 0.7)

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

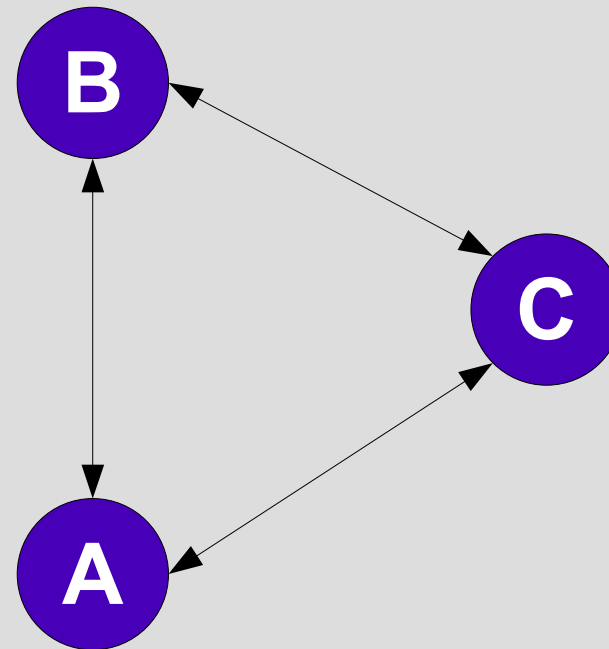# Cyclic MobiSpace ->Probabilistic time-space graph

Cyclic MobiSpace

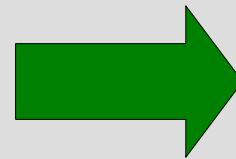*Probabilistic time-space graph G*

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

Cyclic MobiSpace ->Probabilistic time-space graph

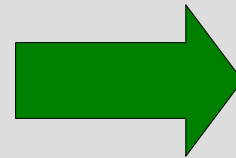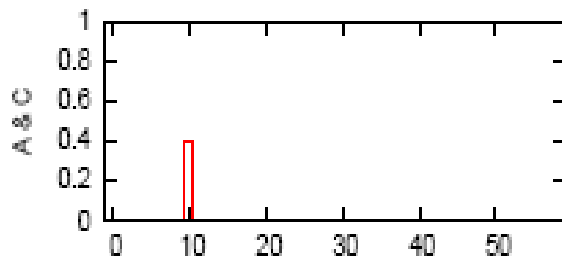*Cyclic MobiSpace*

Probabilistic time-space graph G

(37 , 0.5)

(0 , 0.7)

(30 , 0.7)

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu
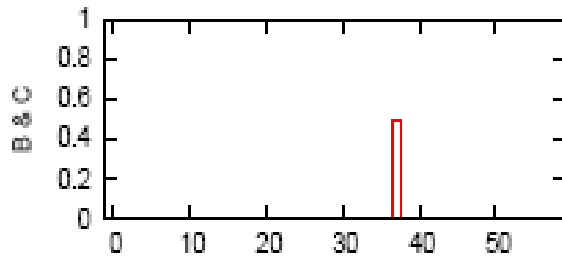
Cyclic MobiSpace ->Probabilistic time-space graph

Cyclic MobiSpace

Probabilistic time-space graph G

*Source: Routing in a Cyclic MobiSpace
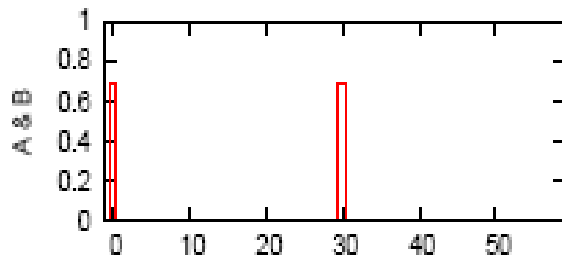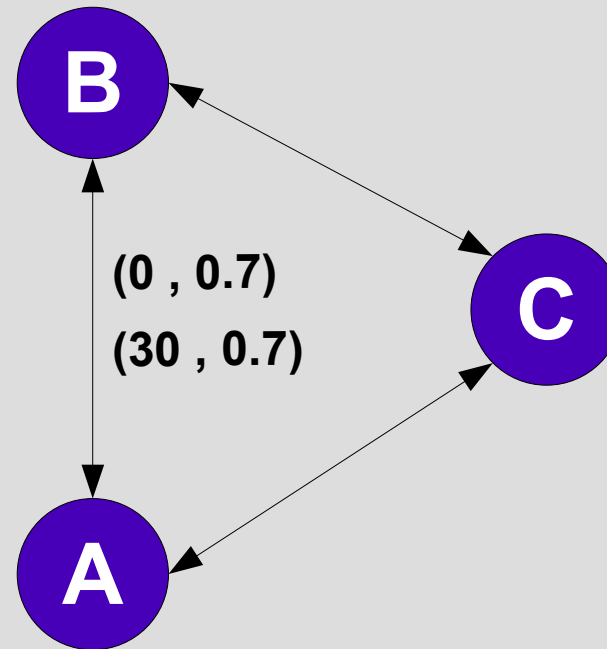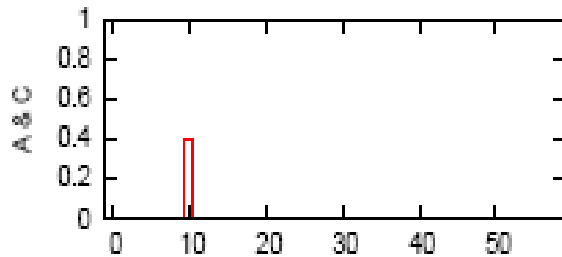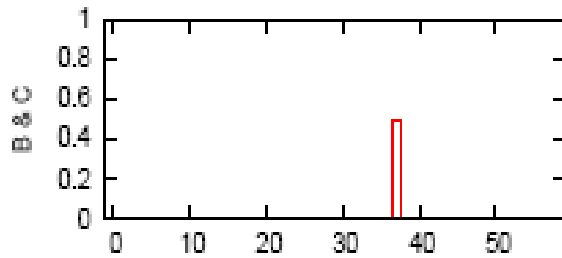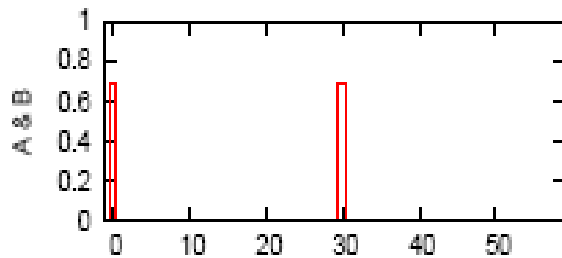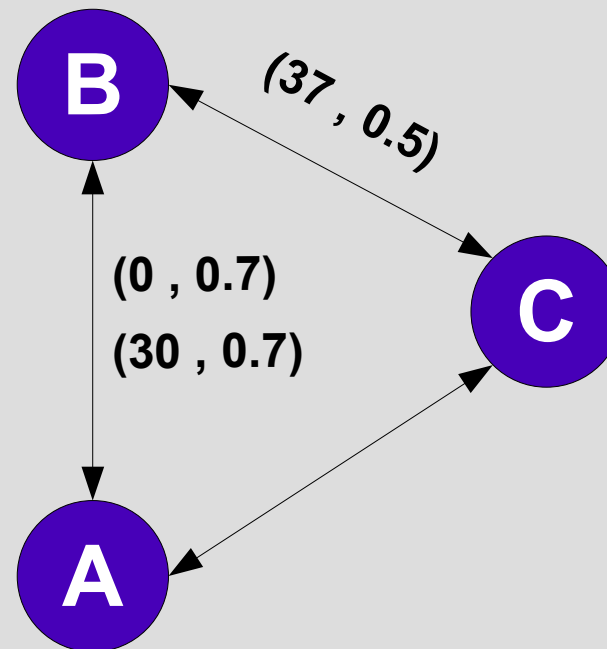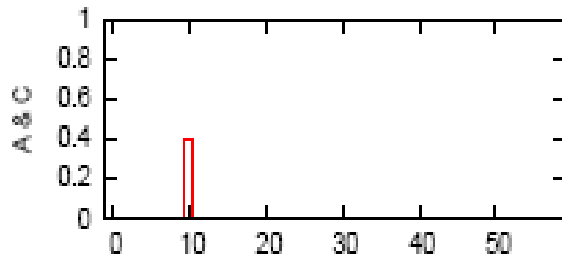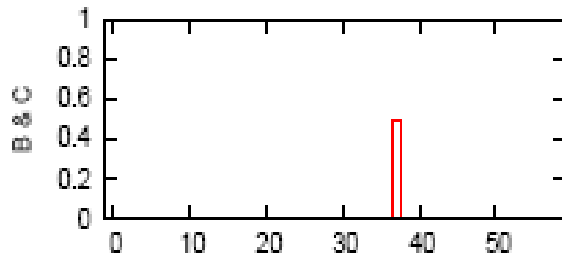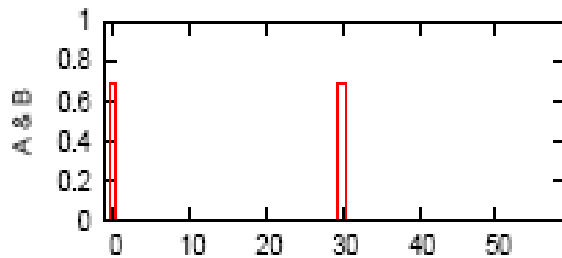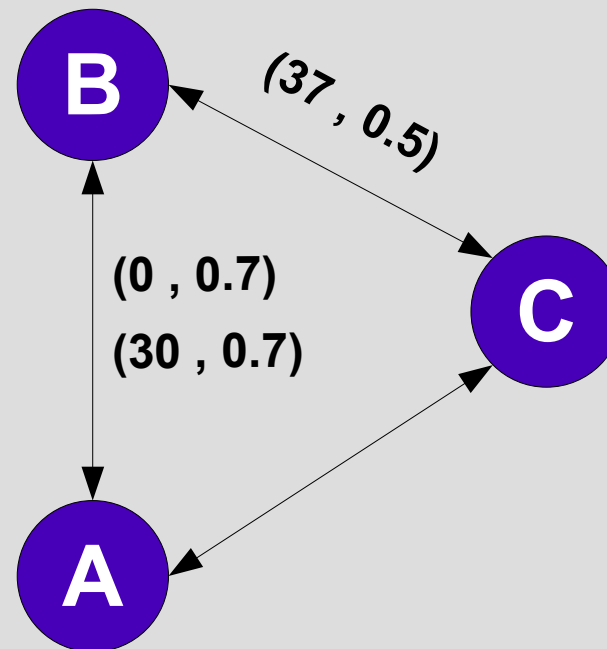Cong Liu and Jie Wu*

Cyclic MobiSpace ->Probabilistic time-space graph

Cyclic MobiSpace

30

20

30

Probabilistic time-space graph G

B

C

A

(37 , 0.5)

(0 , 0.7)

(30 , 0.7)

(10 , 0.4)

Time-state graph -> state-space graph

- Translate the time-space graph G = (V,E,T) to a state space graph G' = (V',E')
- Generation of G':
  - each node u in G create a set of states $\{t_i/u\}$ for every time slot t_i when u have one ore more probabilistic contacts
  - If node u has more than one contact with the same time slot then create only one state for u
  - Two types of links
    - directional (connects consecutive links)
    - bidirectional (connects probabilistic contacts)

Time-state graph -> state-space graph example

Probabilistic time-space graph G

Time-state graph -> state-space graph example

Probabilistic state-space graph G'
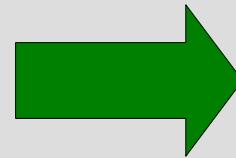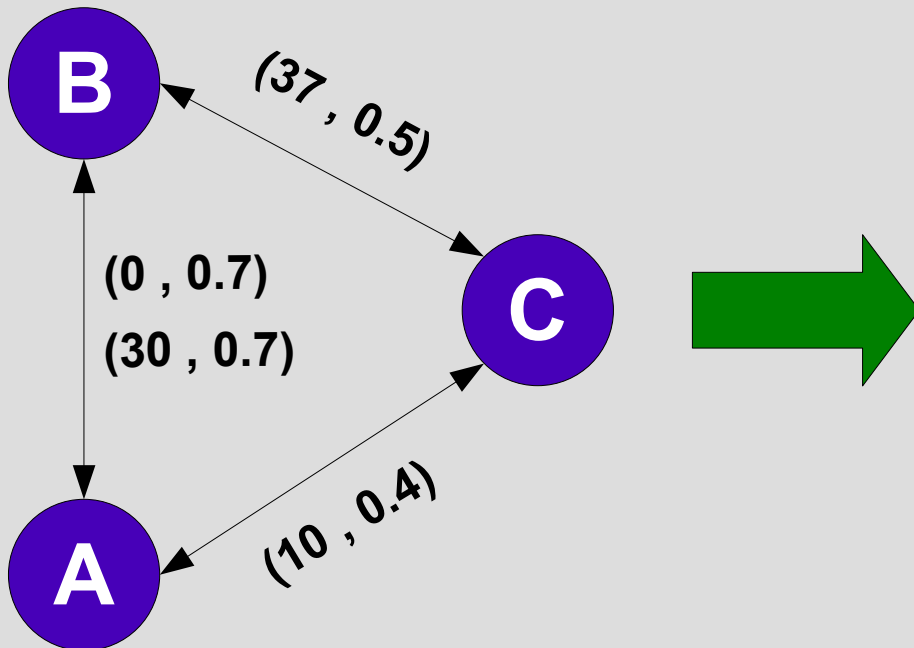
Probabilistic time-space graph G
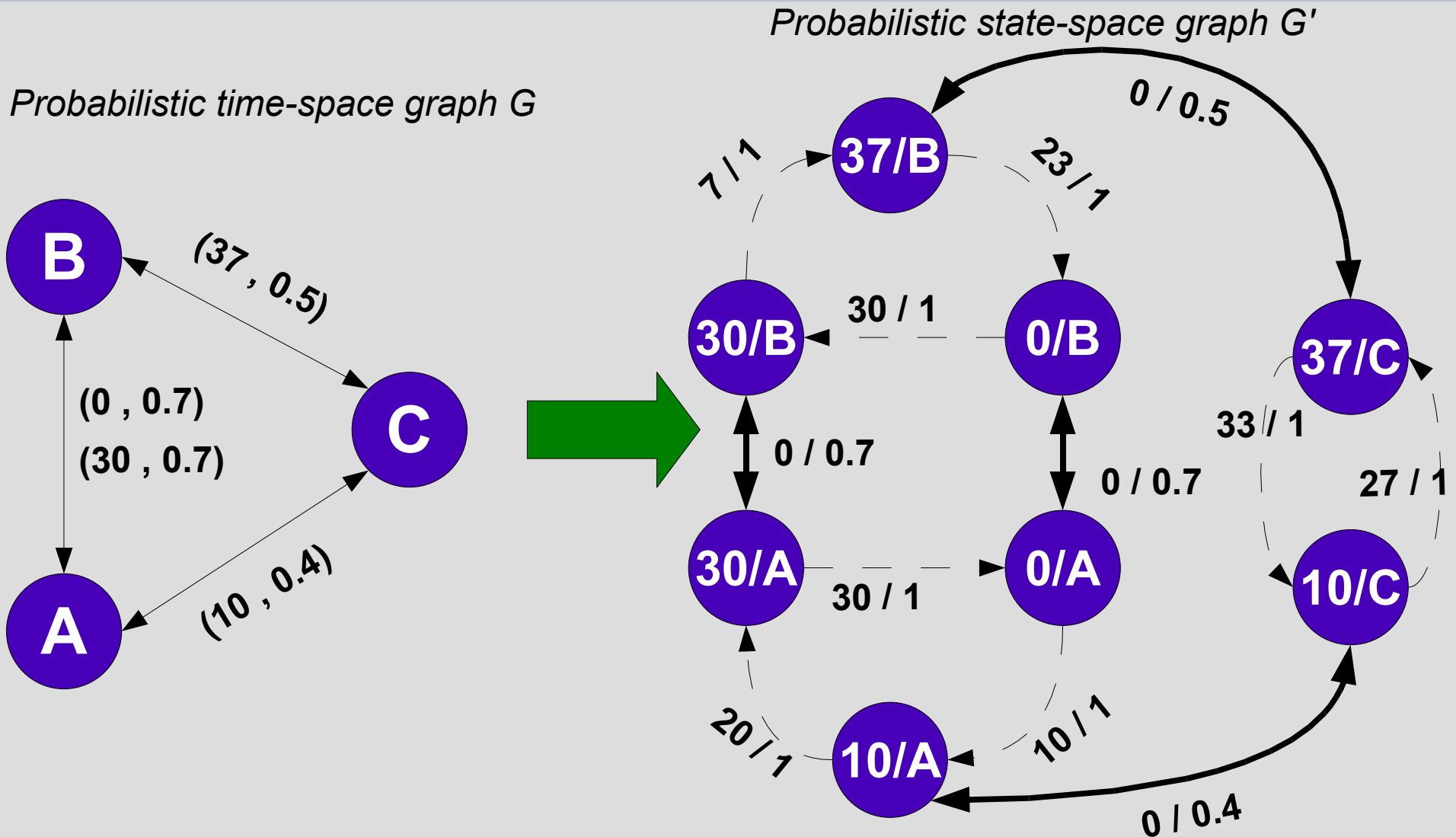
Markov Decission Process (MDP)

MDP is a 5-tupel
(S, A, T, D, S_G)
where
- S: set of all states s
- A: set of all Actions A_S
- $T_a(s,s')$:transition probability functions
- $D(s,s')$: delay function
- S_G: set of the goal states
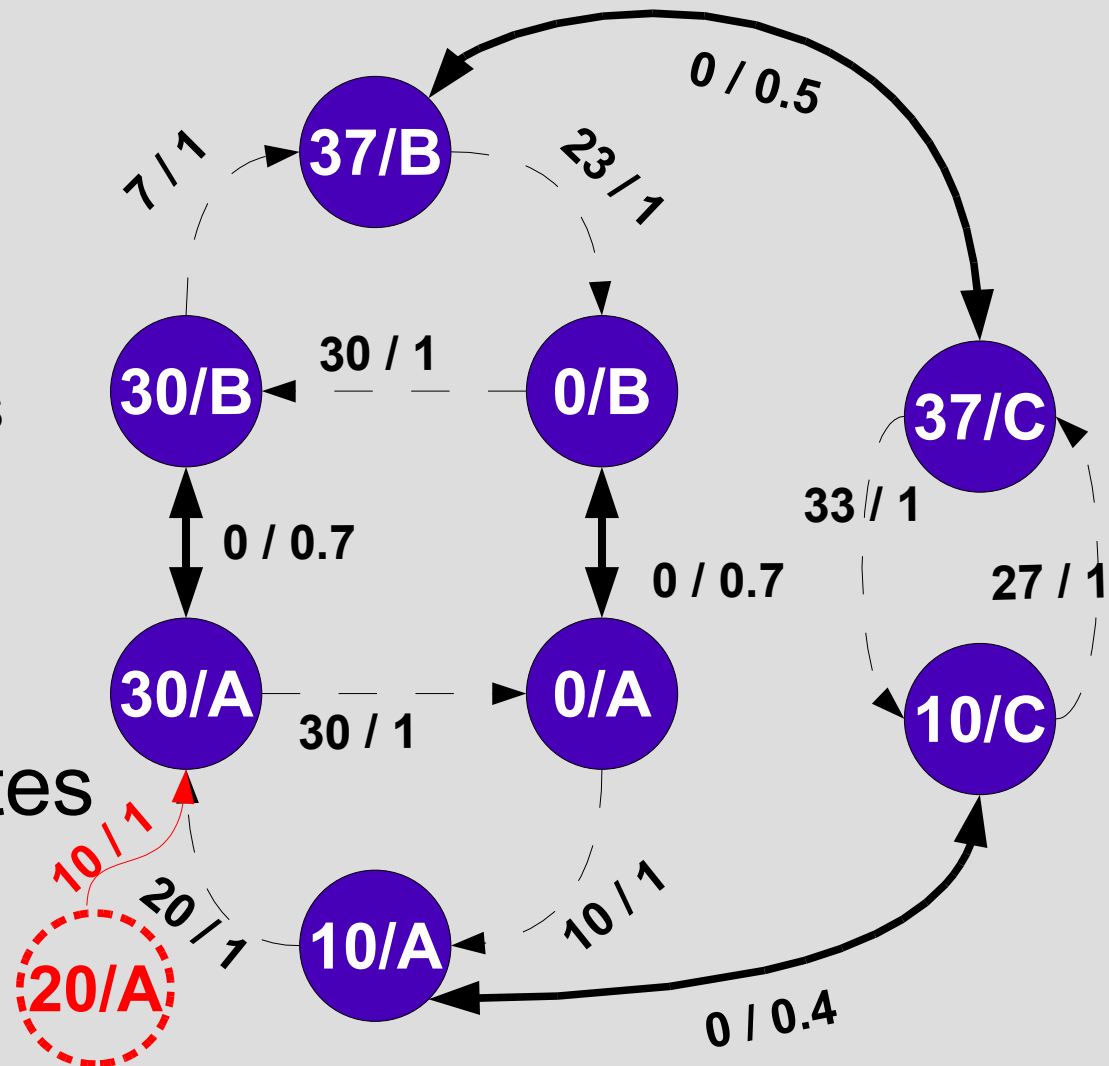
Markov Decission Process (MDP) Solving by value iteration

$$V_{t+1}(s) = \min_{a \in A(s)} \sum_{s' \in S} \{T_a(s, s') \times [D(s, s') + V_t(s')]\}$$

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

After Value Iteration

$$V_{t+1}(s) = \min_{a \in A(s)} \sum_{s' \in S} \{T_a(s, s') \times [D(s, s') + V_t(s')]\}$$
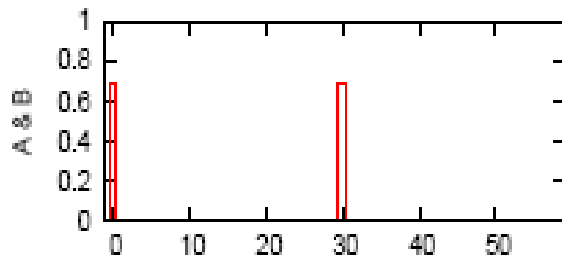
Source: Routing in a Cyclic MobiSpace
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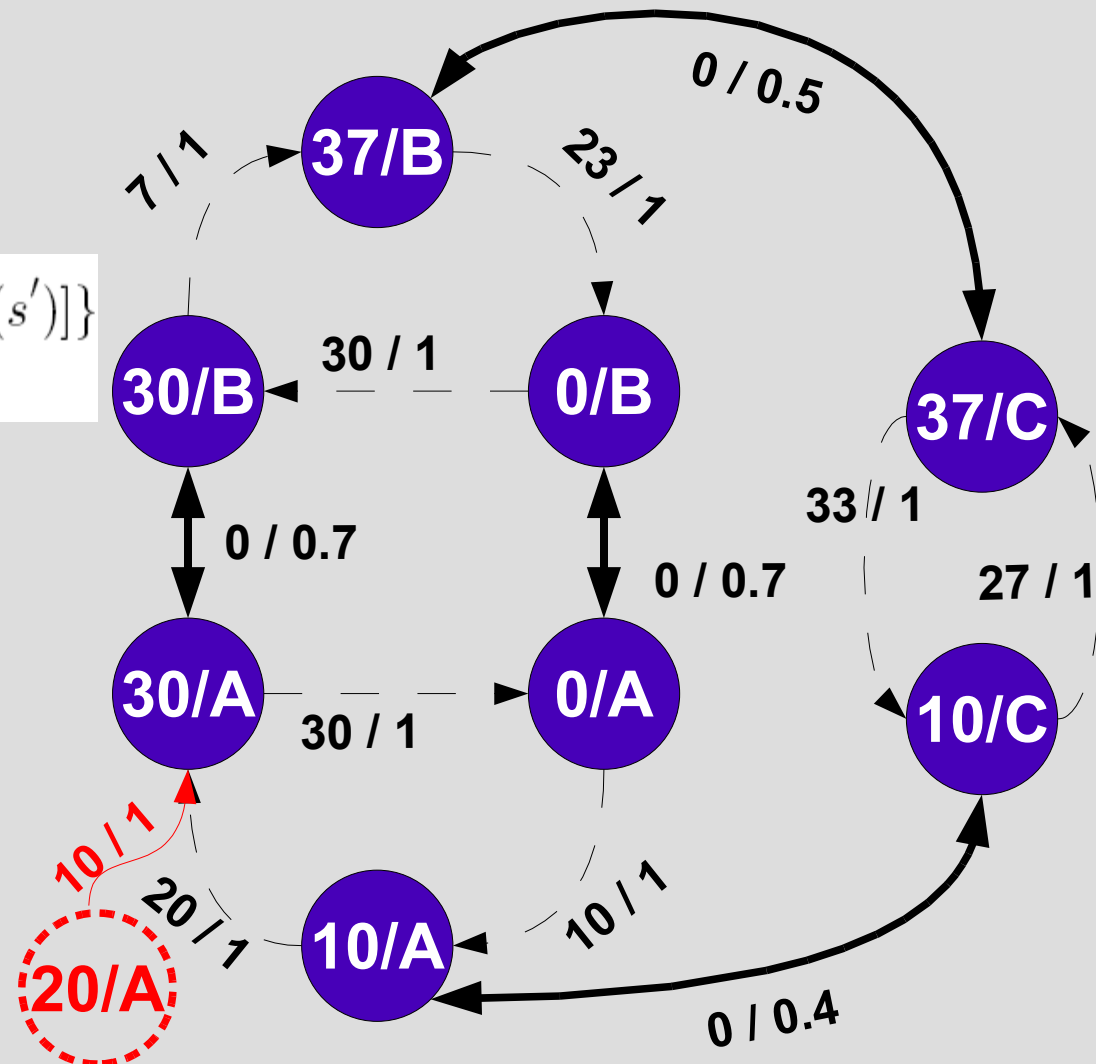
Extended topology value iteration

Extended topology value iteration

The algorithm has two steps:

Step 1:
(a)
choose time slot $t_b = 0$
and remove L_b (the red links)
(b)
add a state s* with its time slot being 3/2 T
(c) for each state s where we had removed an outgoing link make a link from s to s*
then TVI update the components in their reverse topological order

Step 2:
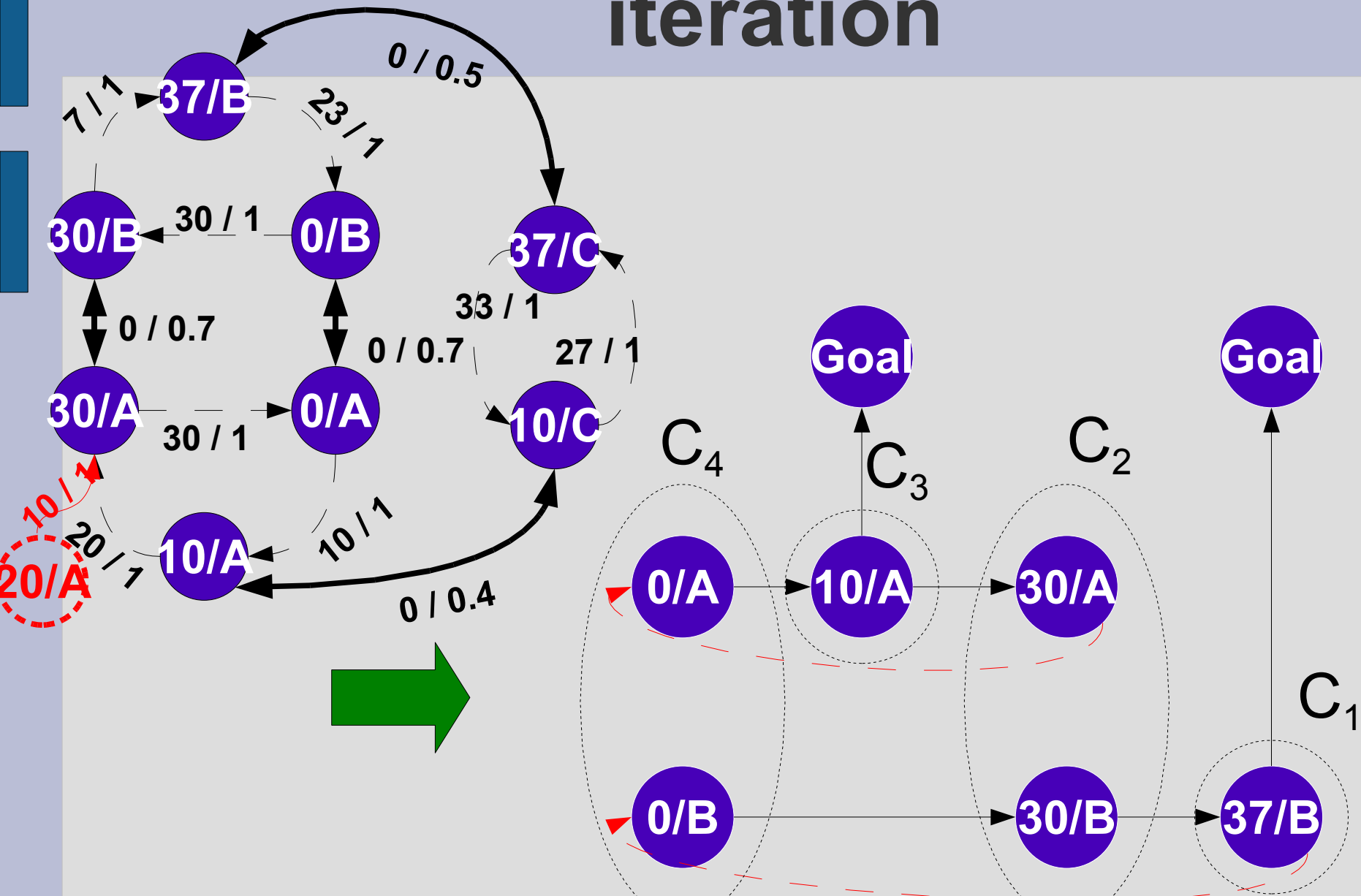then recover the graph and update the components again until all values converge

C_4

C_3

C_2

Goal

Goal

0/A

10/A

30/A

90/1

120/*

0/B

30/B

37/B

C_1

83/1
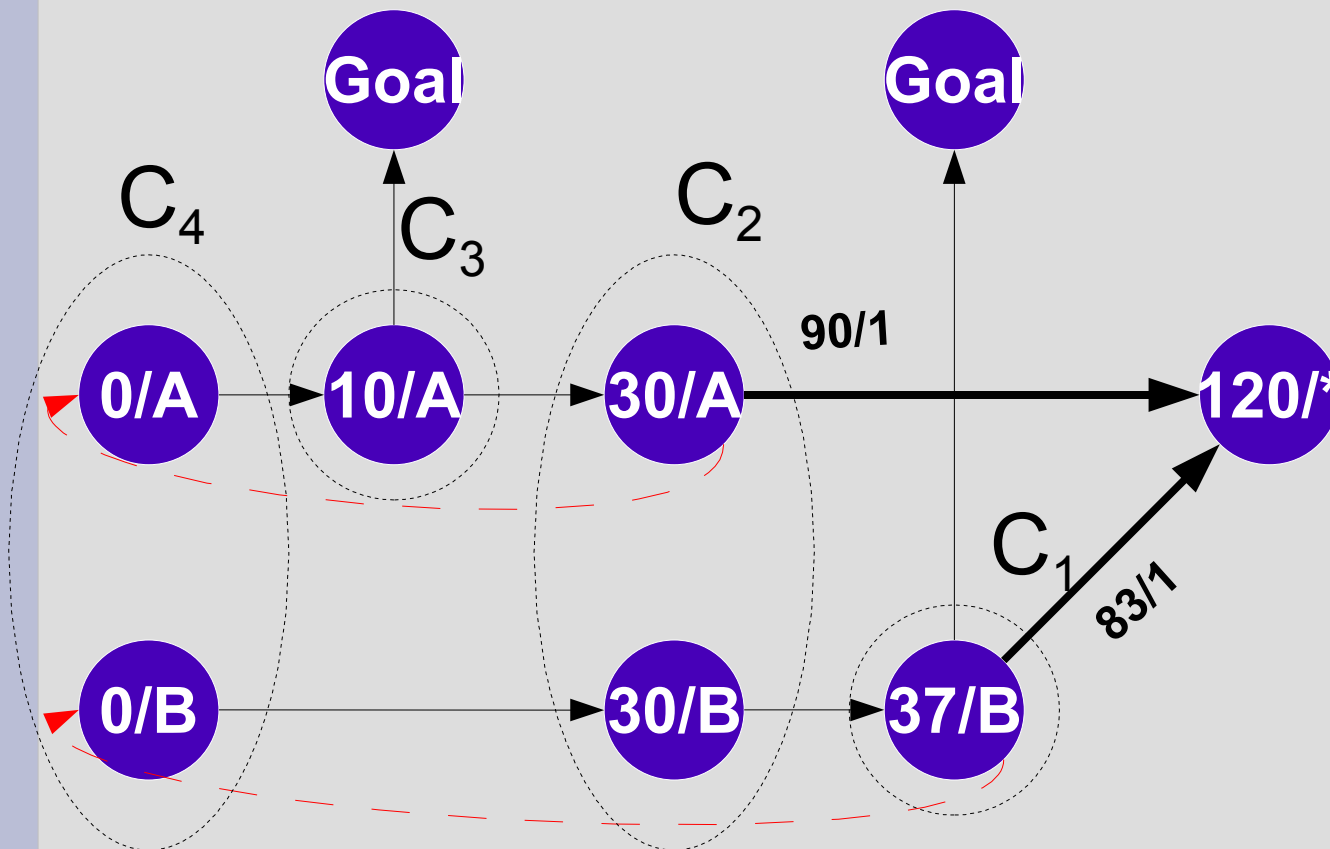
Extended topology value iteration

Table 1: Comparison of value iteration (VI) and our extended topological value iteration (E-TVI).

(a) Resulting value.

states	0/A	0/B	10/A	30/A	30/B	37/B
VI	59.87	66.41	49.88	63.14	51.70	44.70
E-TVI	59.92	66.46	49.91	63.19	51.73	44.73

(b) Computation time.

nodes	100	200	300	400	500
VI	0.515	1.256	3.515	7.194	10.25
E-TVI	0.137	0.360	0.668	1.225	2.426

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

Comparison of protocols

- **Epidemic:** (greedy, sends a copy to every new note, which didn't get a copy already)
- **Spray&wait:** (controls number of copies)
  - node i will only copy a message to j if i owns N>1 tickets.
  - i gives L = $\lfloor N/2 \rfloor$
  - i remains N – L tickets
- **Spray&focus:** (extension of Spray&wait)
  - Even for i only owns N = 1 tickets, the message could be copied to j, if j have an higher delivery probability
- **MaxProp** (cost based)
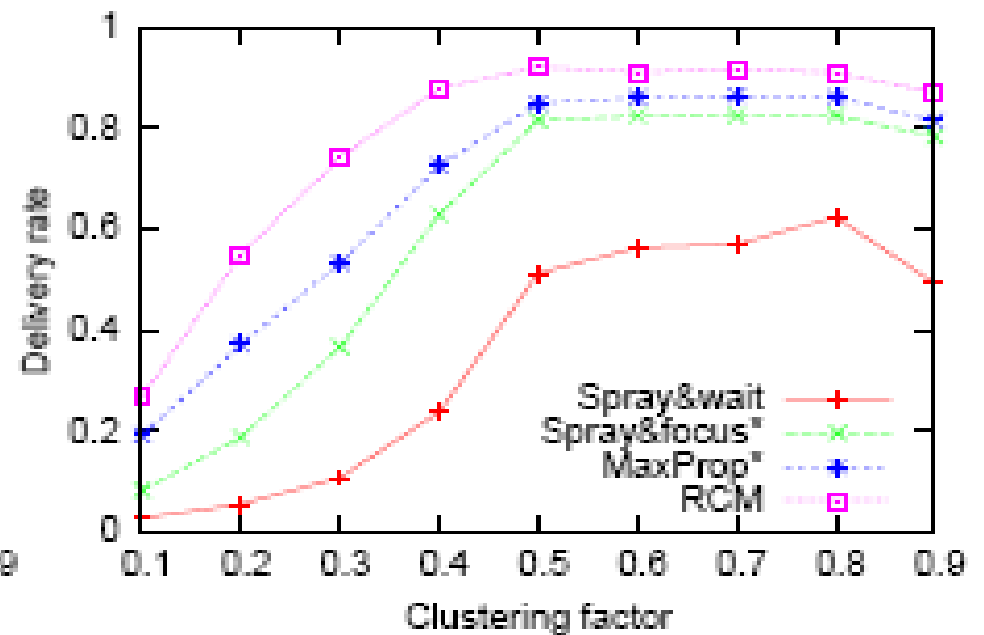
Different traces

- NUS student contact trace
  - Students in a class
  - Contacts
  - Hour is the unit time for the contact duration
- UmassDieselNet trace
  - Bus to bus contacts of 40 buses were logged
- Synthetic Bus trace
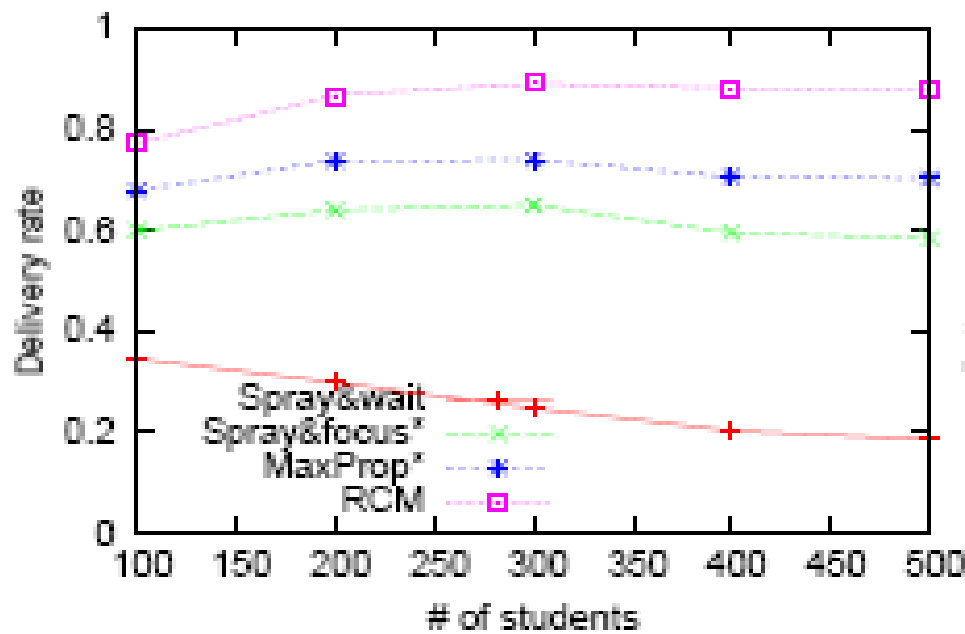 - Generated from maps from Subway in Miami and Metro in Madrid

Source: Routing in a Cyclic MobiSpace
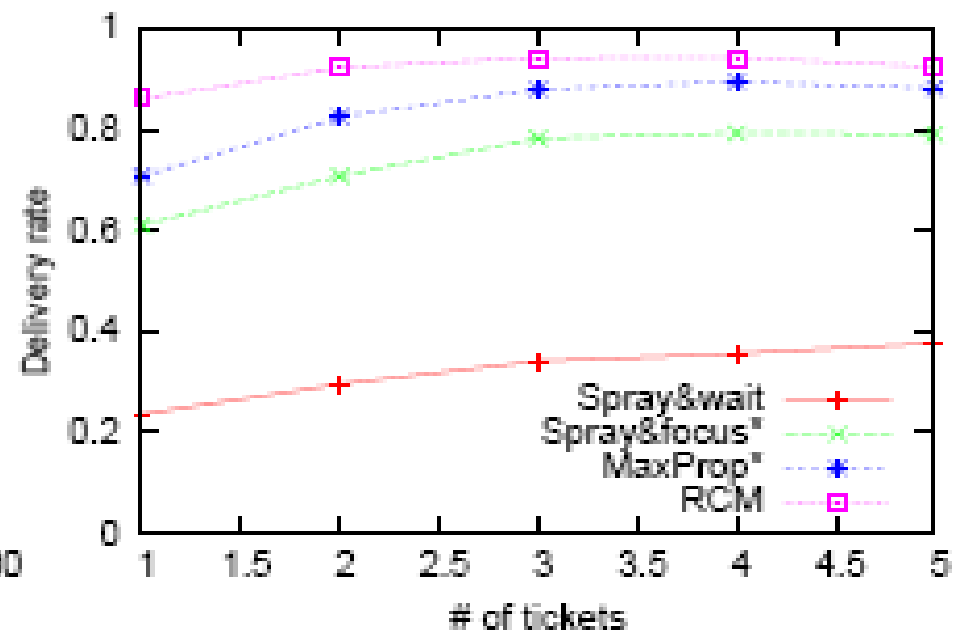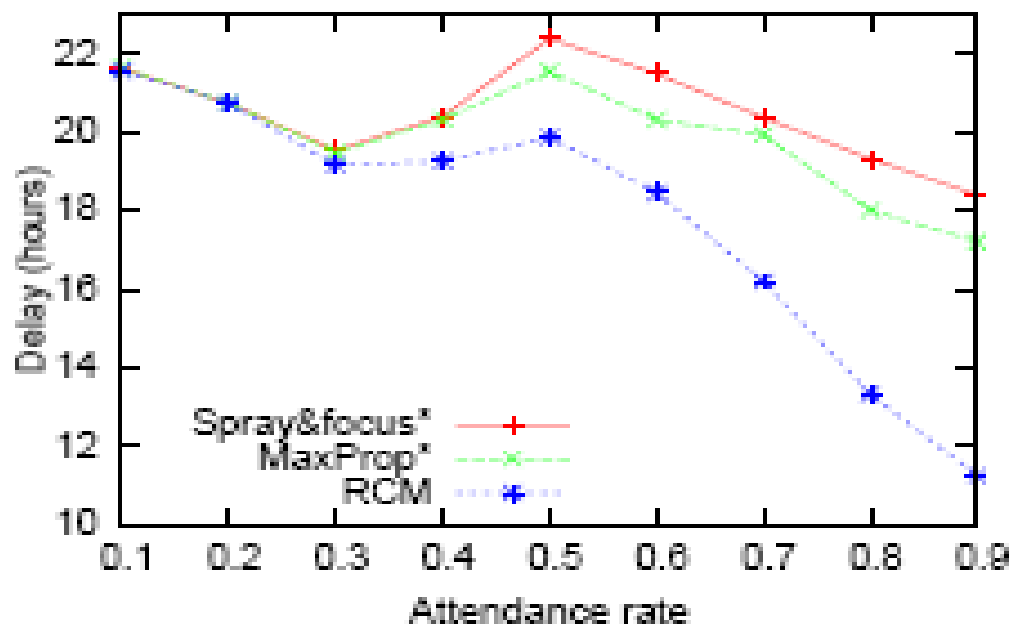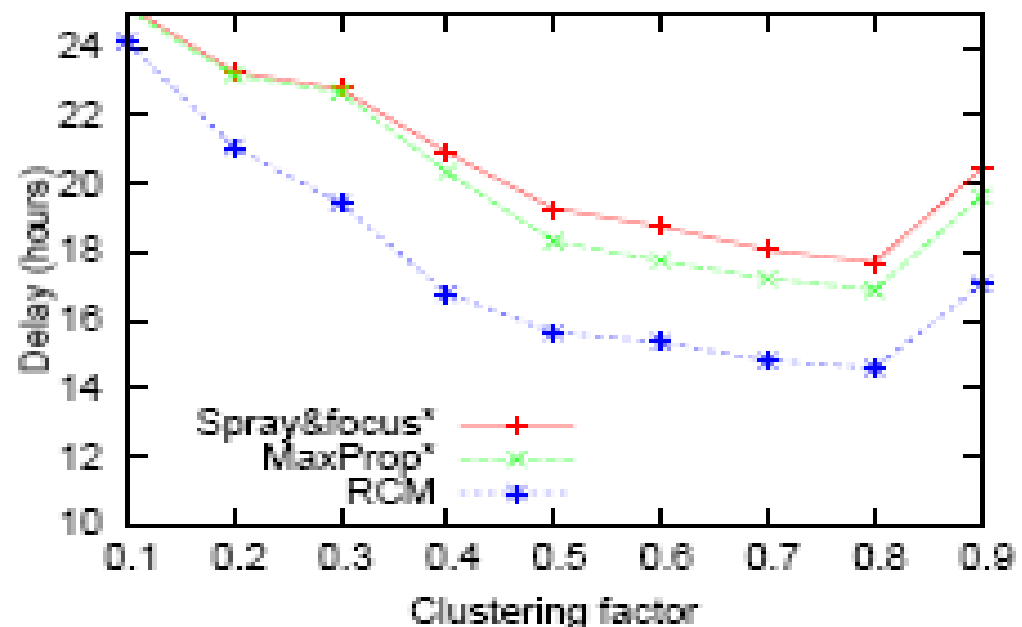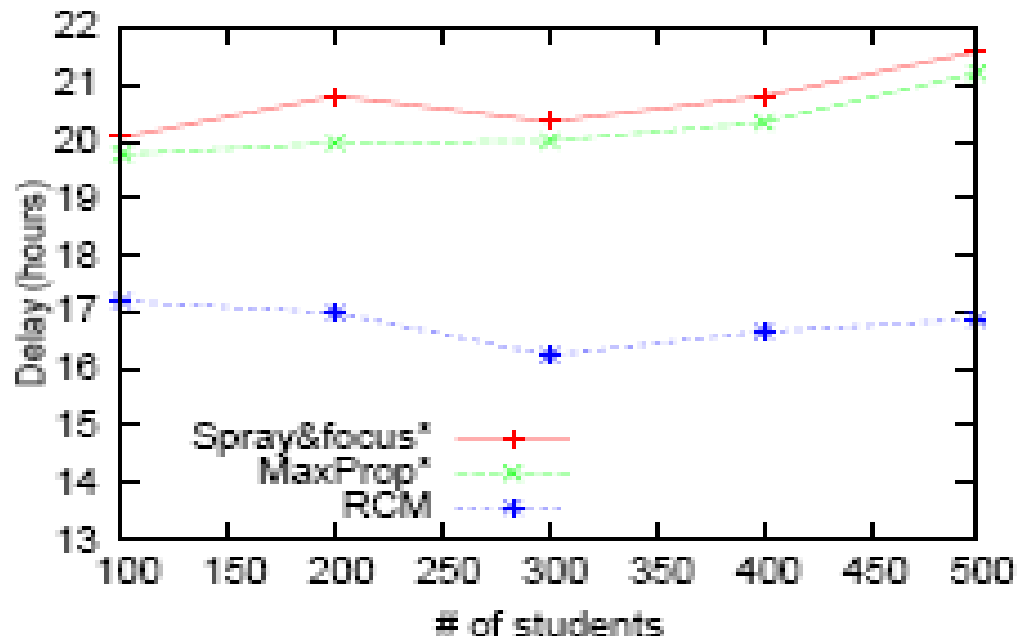*Cong Liu and Jie Wu*
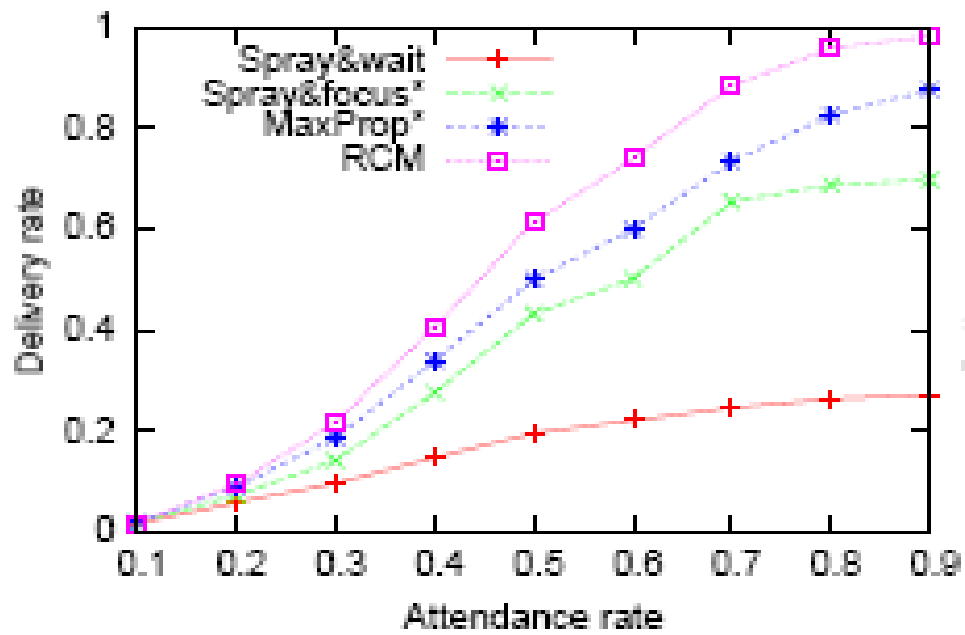
(a)

(b)

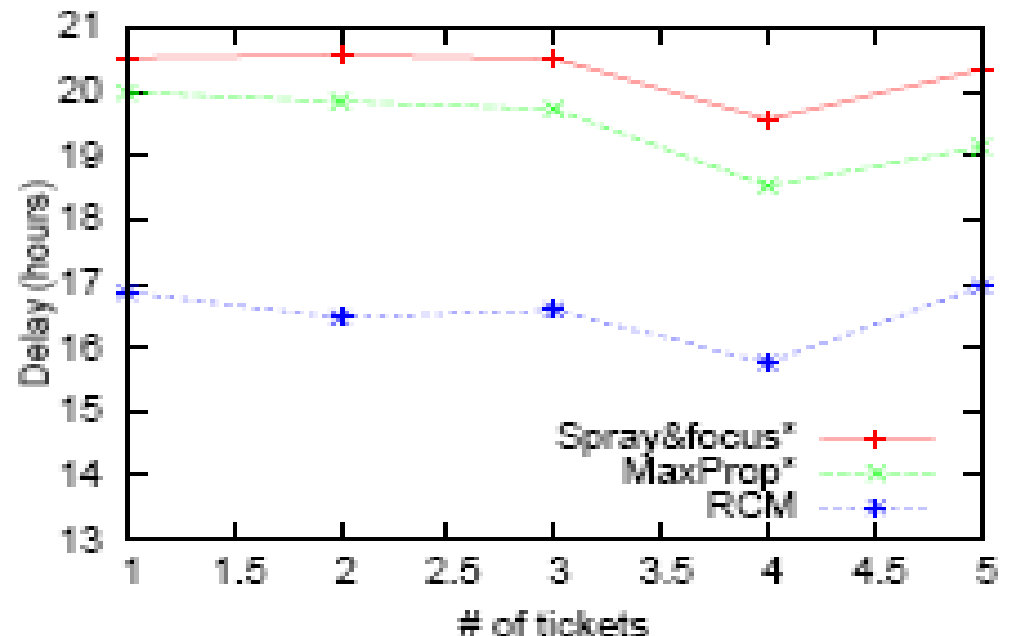(c) *Source: Routing in a Cyclic MobiSpace* (d)
Cong Liu and Jie Wu

Source: Routing in a Cyclic MobiSpace
Cong Liu and Jie Wu

The End /Questions

Thank you for your attention