DATA ROUTING IN A BUS-BASED DTN

Maestro retreat, Avignon 22 Sept. 2009

Giovanni Neglia

Joint work with Paolo Giaccone, David Hay, Leonardo Rocha

and Saed Tarapiah (new entry)

How to selfishly exploit Maestro retreat to get feedbacks on ongoing works

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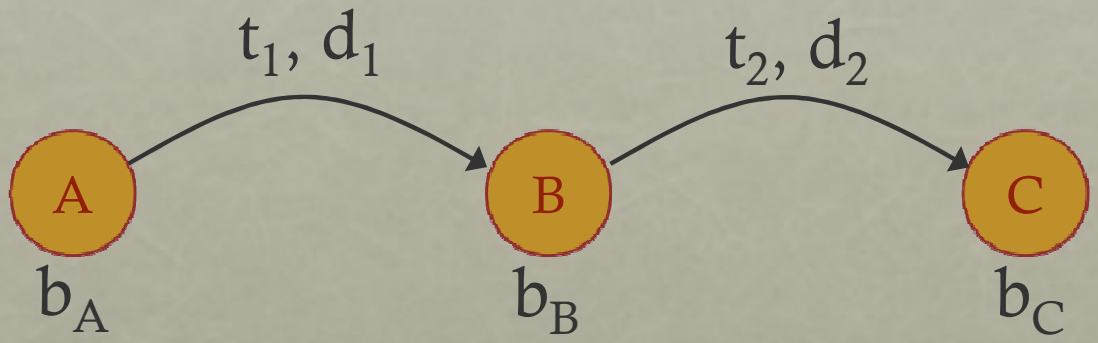
MOBILITY MODELS FOR DTNS

- (almost) Zero knowledge about future meetings
  - Random waypoint model, random direction model, …
  - Copies (not only forwarding) necessary to guarantee fast delivery time
- Complete knowledge about future meetings
  - Deterministic single-copy routing
  - It is possible to apply standard algorithms for static graphs

TRANSFORMING A TIME – DEPENDENT DTN GRAPH



t_i: meeting time instant
d_i: max amount of data transferable
b_i: buffer size at node x

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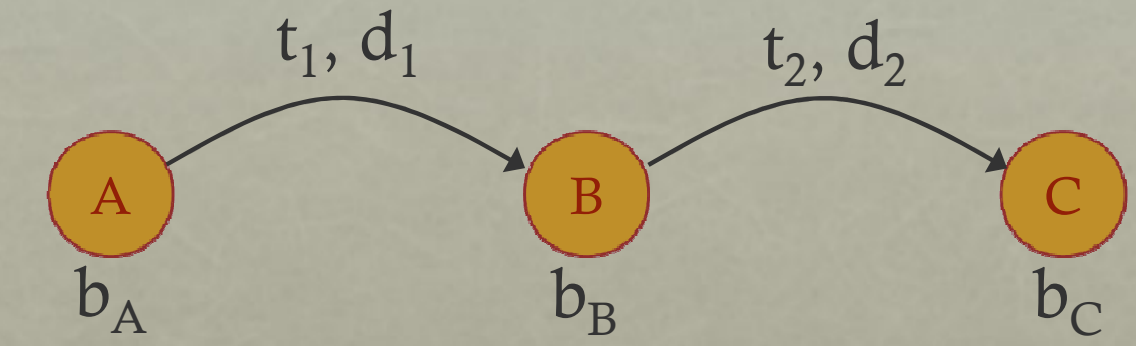

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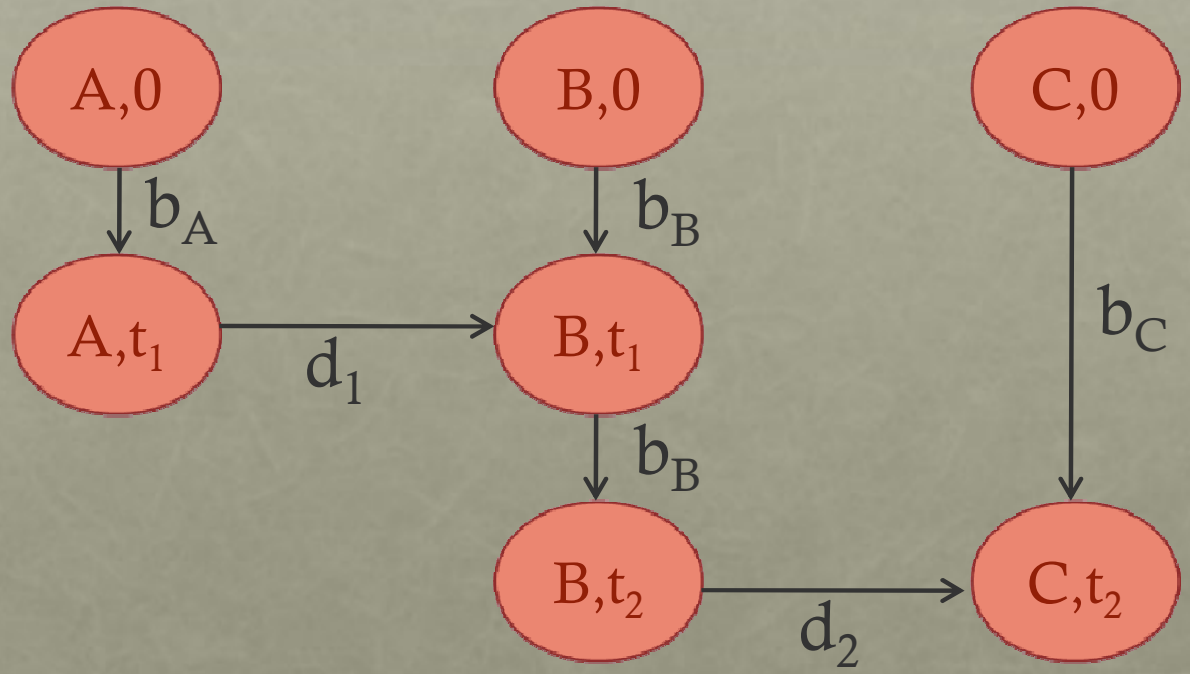

Path from A to C?

Maximum data transferable?

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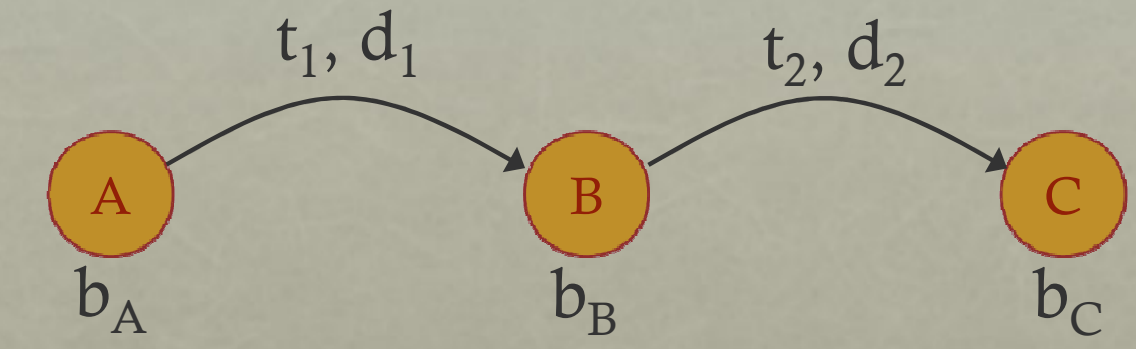

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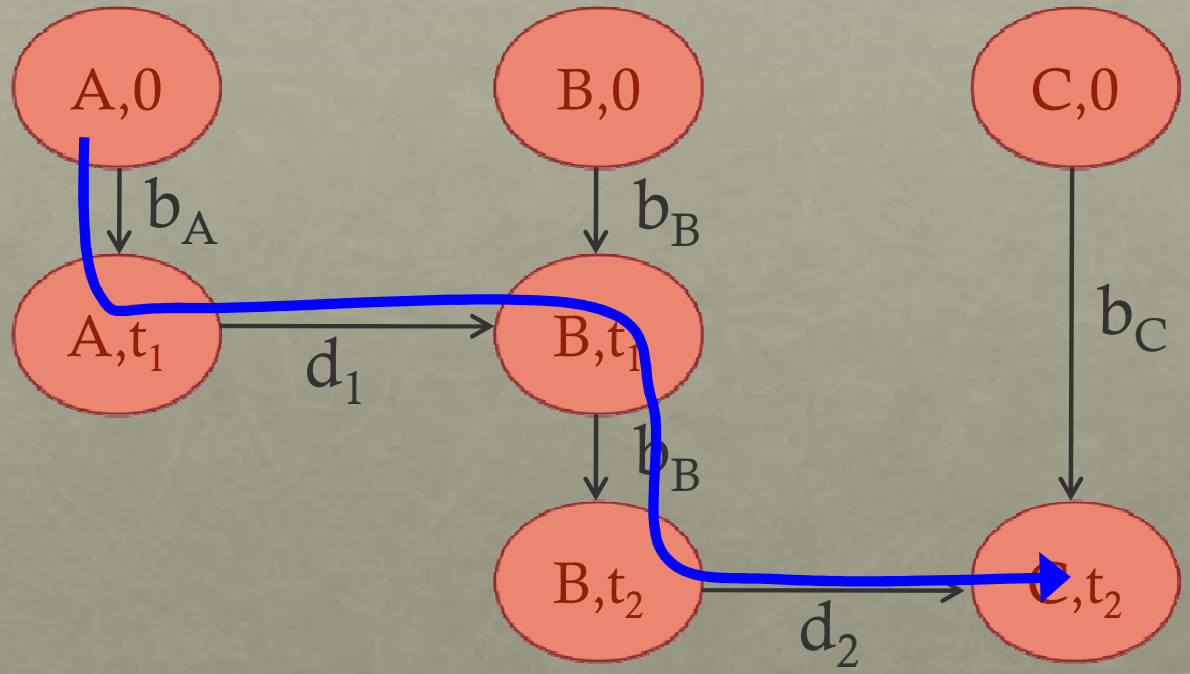
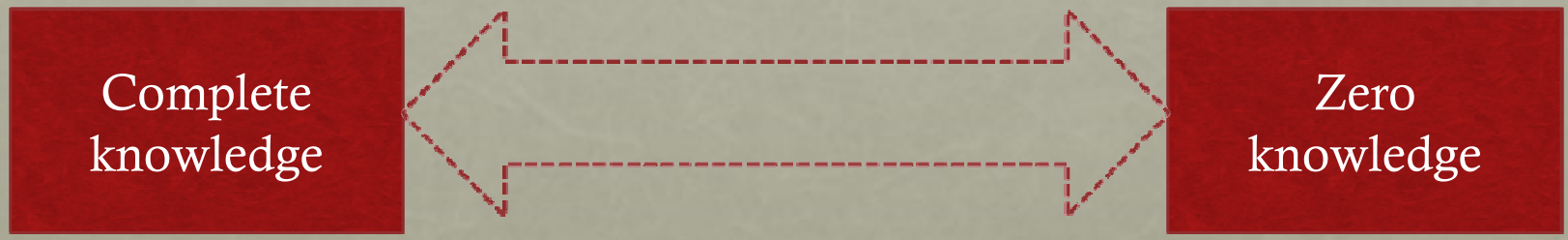


Path from A to C?
YES
Maximum data transferable?
$\max\{b_A, d_1, b_B, d_2\}$

SOMETHING IN THE MIDDLE?



WHERE WE PLACE OURSELVES

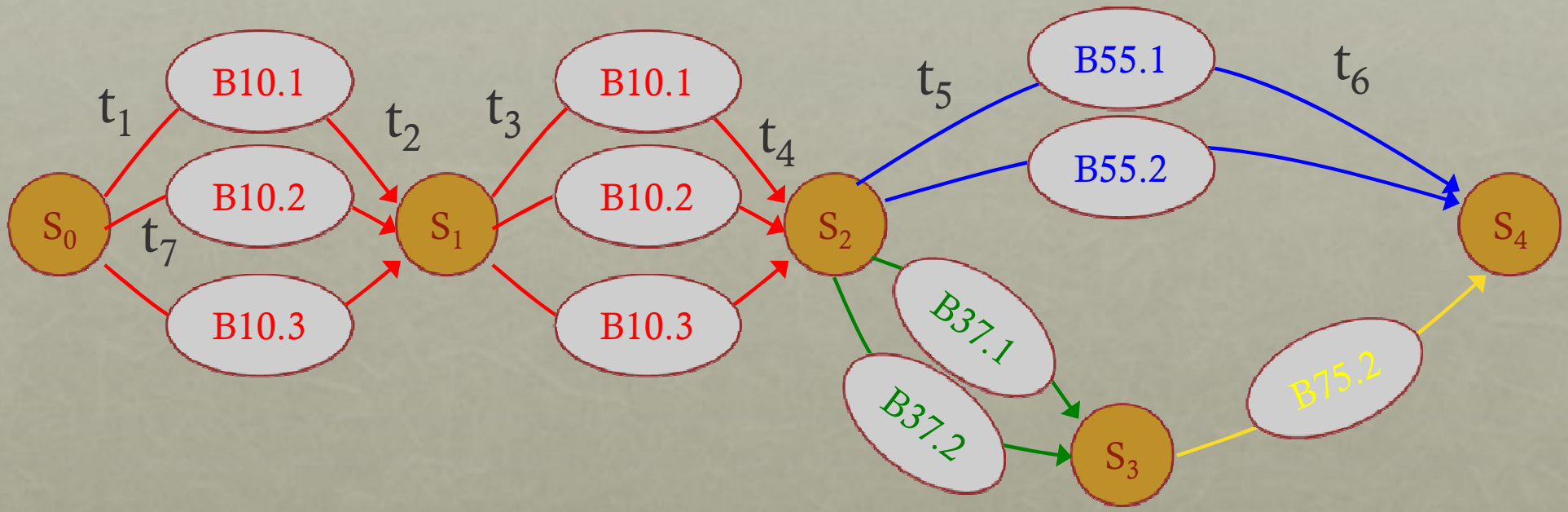
Quasi-deterministic mobility

- **There is some information available a priori (e.g. a schedule)**
- **But also some (small) noise affecting expected meeting time**

A CASE STUDY: A BUS-BASED DTN

- Turin bus transportation system
  - about 60 schedule-based bus lines
  - about 50 frequency-based bus lines (up to 12 buses per hour)
  - About 3000 bus stops
- Route a message from a source to a destination
  - using only bus-stop meetings (for which we have a schedule) and stop2stop transfers
  - target: maximize delivery probability
    - by a given deadline T
    - with not too many copies
- What different from people routing?
  - Messages cannot walk…
  - but can be duplicated

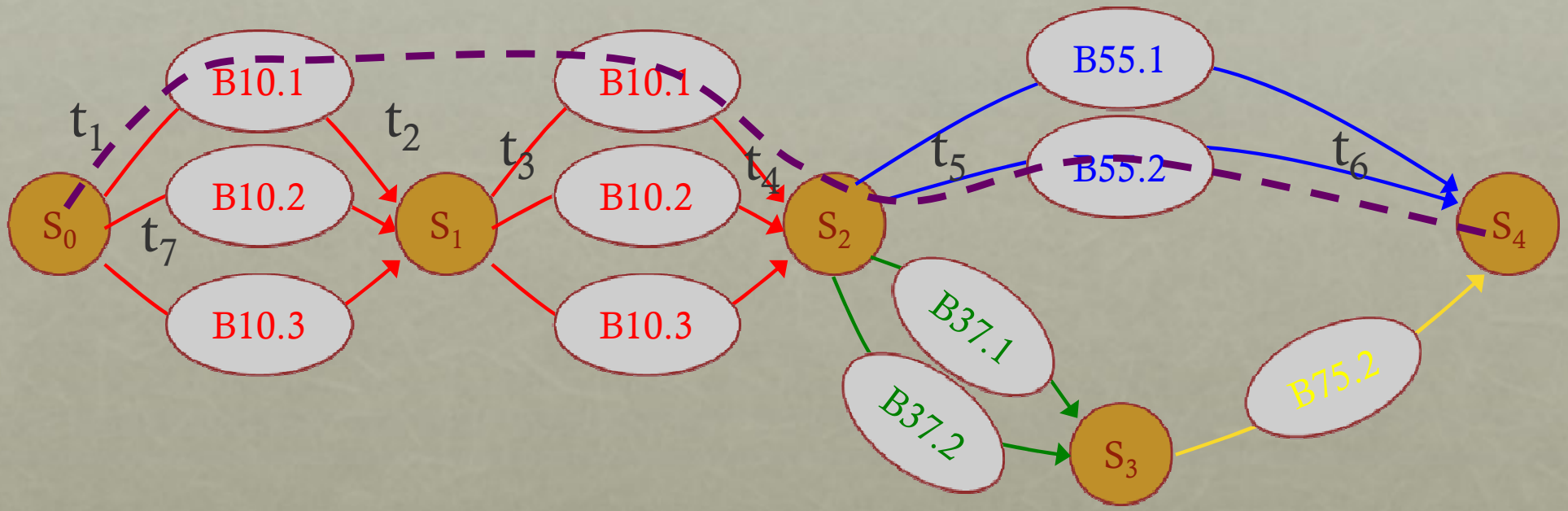
THE DTN GRAPH



Bn.m m-th vehicle of line n

t_i scheduled meeting time

THE DTN GRAPH

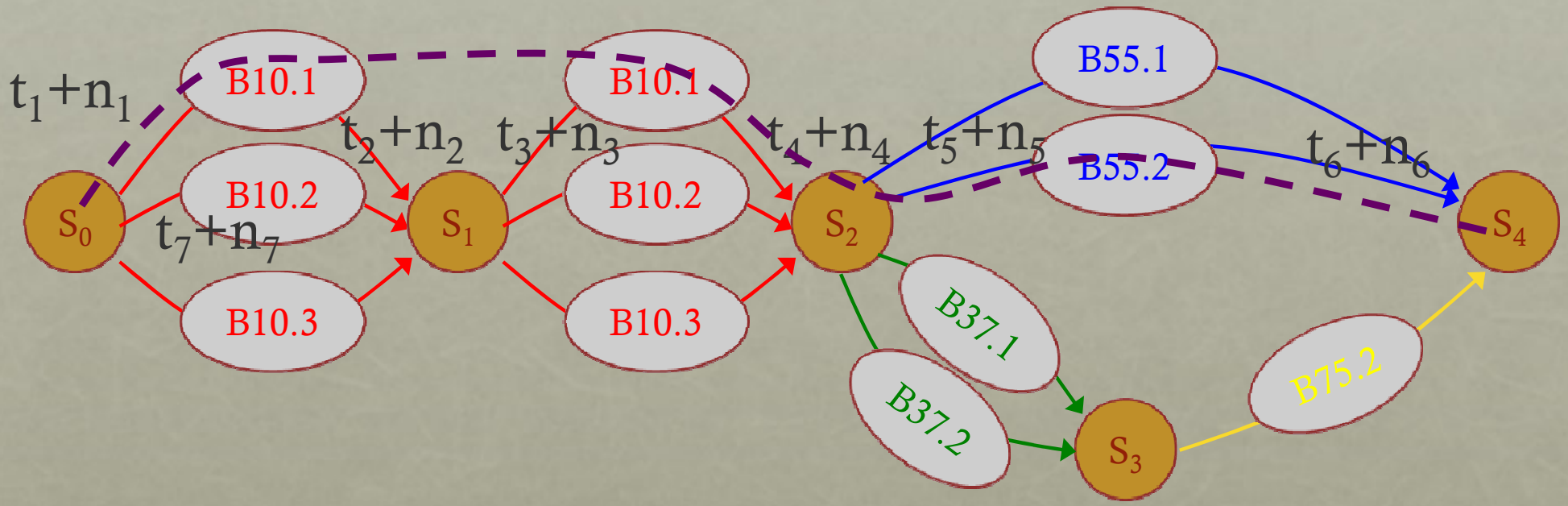


A <u>feasible</u> vehicle path if $t_4 <= t_5$ and $t_6 <= T$

Bn.m m-th vehicle of line n

t_i scheduled meeting time

THE DTN GRAPH

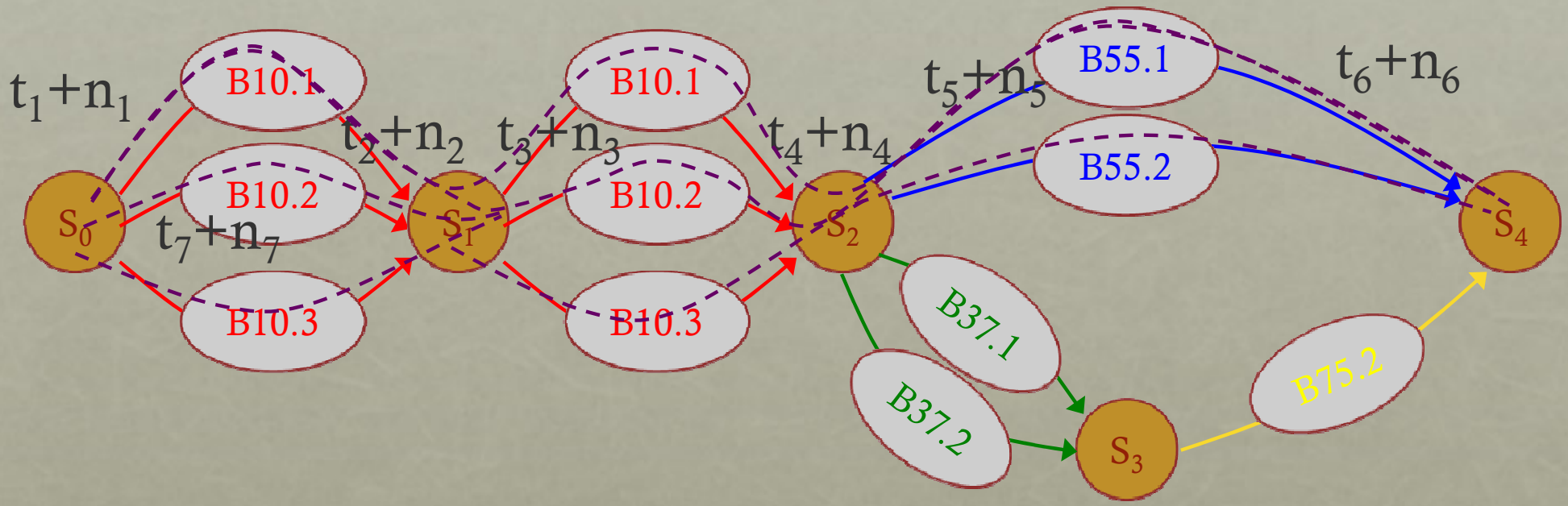


An <u>actual</u> vehicle path if $t_4+n_4 <= t_5+n_5$ and $t_6+n_6 <= T$

Bn.m m-th vehicle of line n

t_i scheduled meeting time

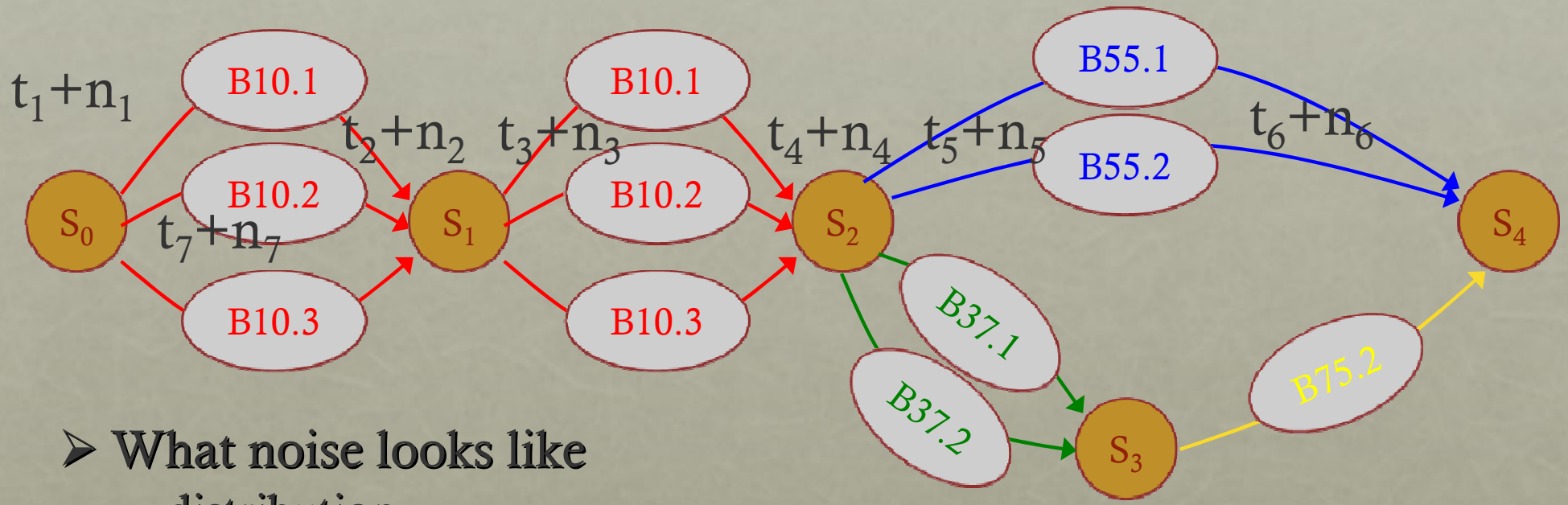
THE DTN GRAPH



The corresponding line path:

- take the 1st bus of line 10 arriving at stop S_0
- get off at stop S_2
- take the 1st bus of line 55 arriving at stop S_2
- get off at stop S_4

OPTIMAL ROUTING: KEY ISSUES



- What noise looks like
  - distribution
  - Temporal and spatial noise correlation
    - n_1 correlated with n_2 (e.g. necessarily $t_1+n_1 \leq t_2+n_2$
    - n_1 correlated with n_7 (e.g. if there is traffic nearby stop S_0)
- Max delivery prob. not equivalent to max a link-additive cost
  - No standard routing algorithms

BUS MOVEMENT NOISE

- Look for known results in transportation networks
  - Models
  - Measurements
  - Traffic simulators

- Look directly in real traces

BUS MOVEMENT NOISE

- Look for known results in transportation networks
  - Models
  - Measurements
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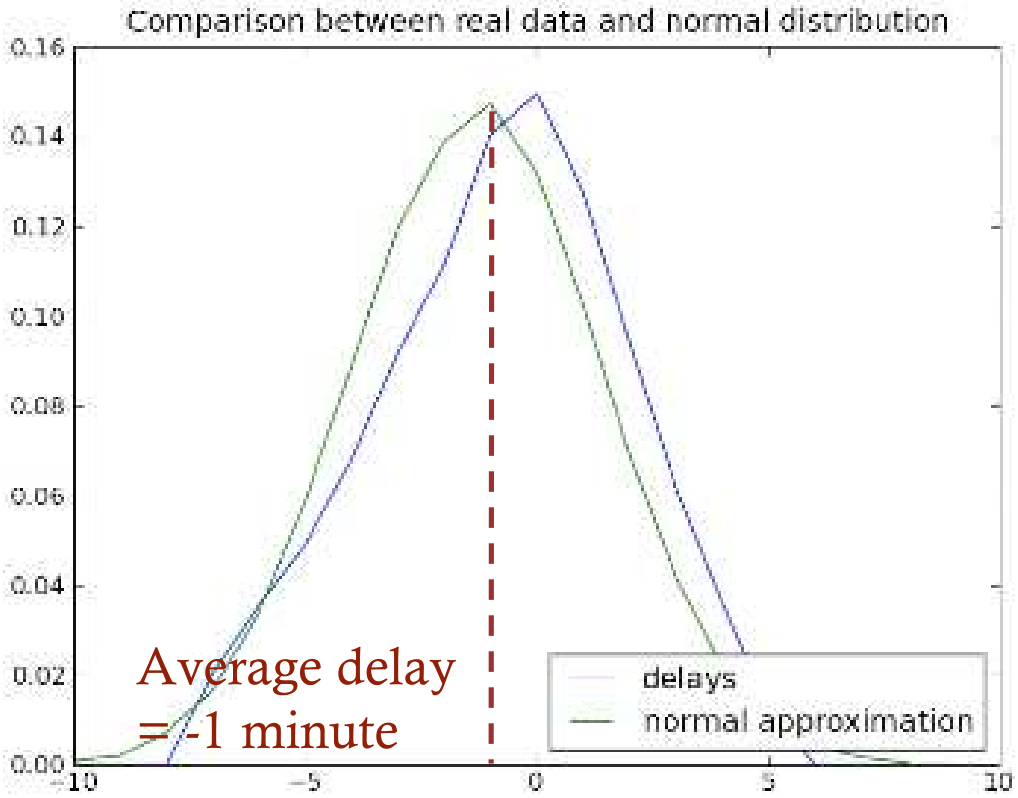
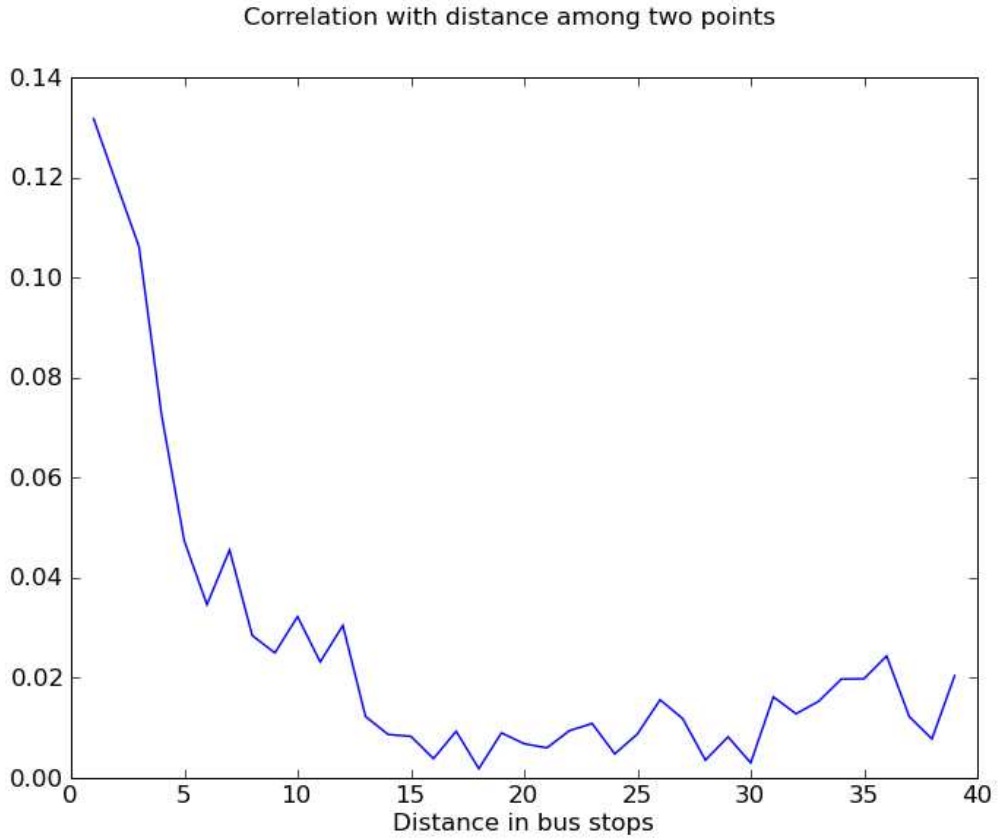
  The expert answer: "Have you googled it?"

- Look directly in real traces

  Provided by Turin transportation system (GTT)

TURIN TRACES





Ask to GTT engineers:
"There is probably a problem somewhere.
Thanks to help us debugging the system"

ROUTING ALGORITHM

1. Find the vehicle path that maximizes the waiting time at each stop while respecting the deadline T
   - similar to what we do when planning flight trips

2. Estimate its delivery probability
   - assuming noise independence at different bus stops
   - $P=(s_0,e_0,s_1,e_1,\ldots s_{n-1},e_{n-1},s_n)$

     $\text{Prob}\{P \text{ is successful}\} = \text{Prob}\{t_{0,1} \le t_{0,2} \le t_{1,1} \le t_{1,2} \le \ldots t_{n-1,1} \le t_{n-1,2} \le T\} =$

     $= \text{Prob}\{t_{0,1} \le t_{0,2}\}\ \text{Prob}\{t_{0,2} \le t_{1,1} \mid t_{0,1} \le t_{0,2}\}$

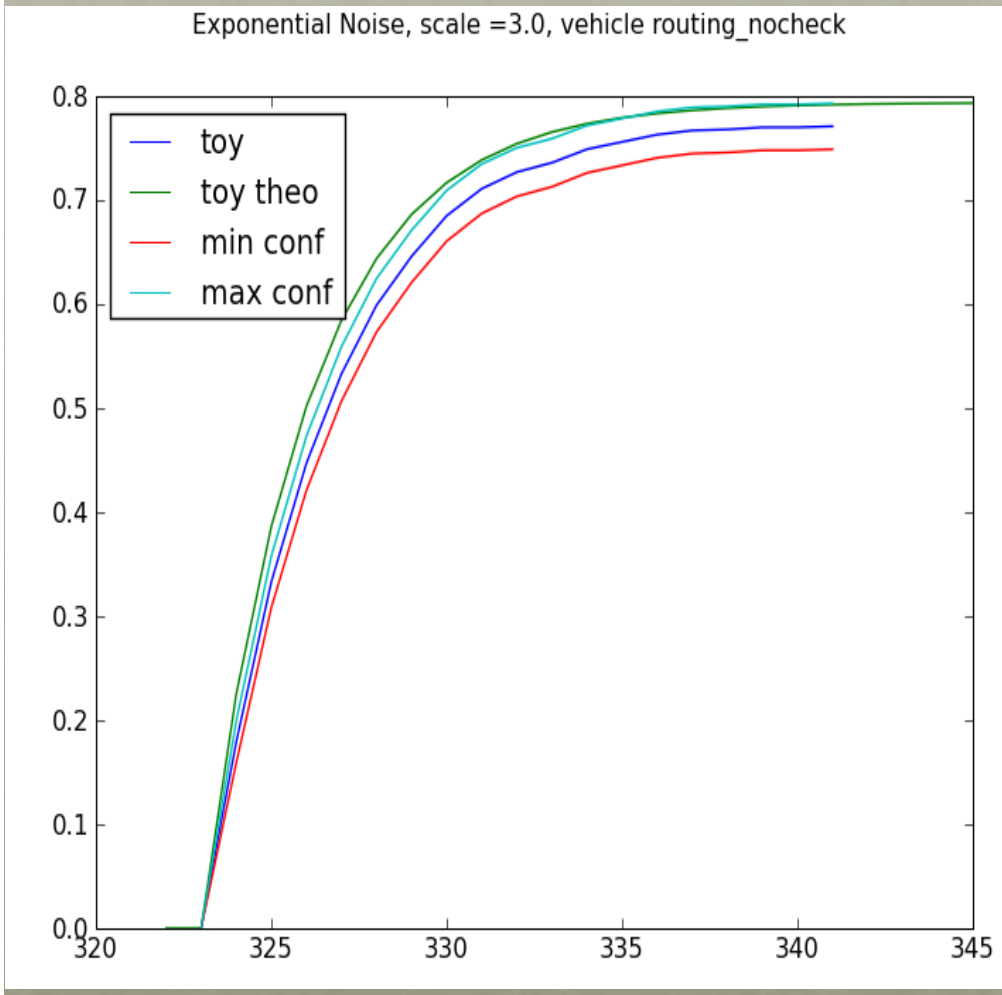
     $\text{Prob}\{t_{1,1} \le t_{1,2} \mid t_{0,1} \le t_{0,2} \le t_{1,1}\} \ldots$

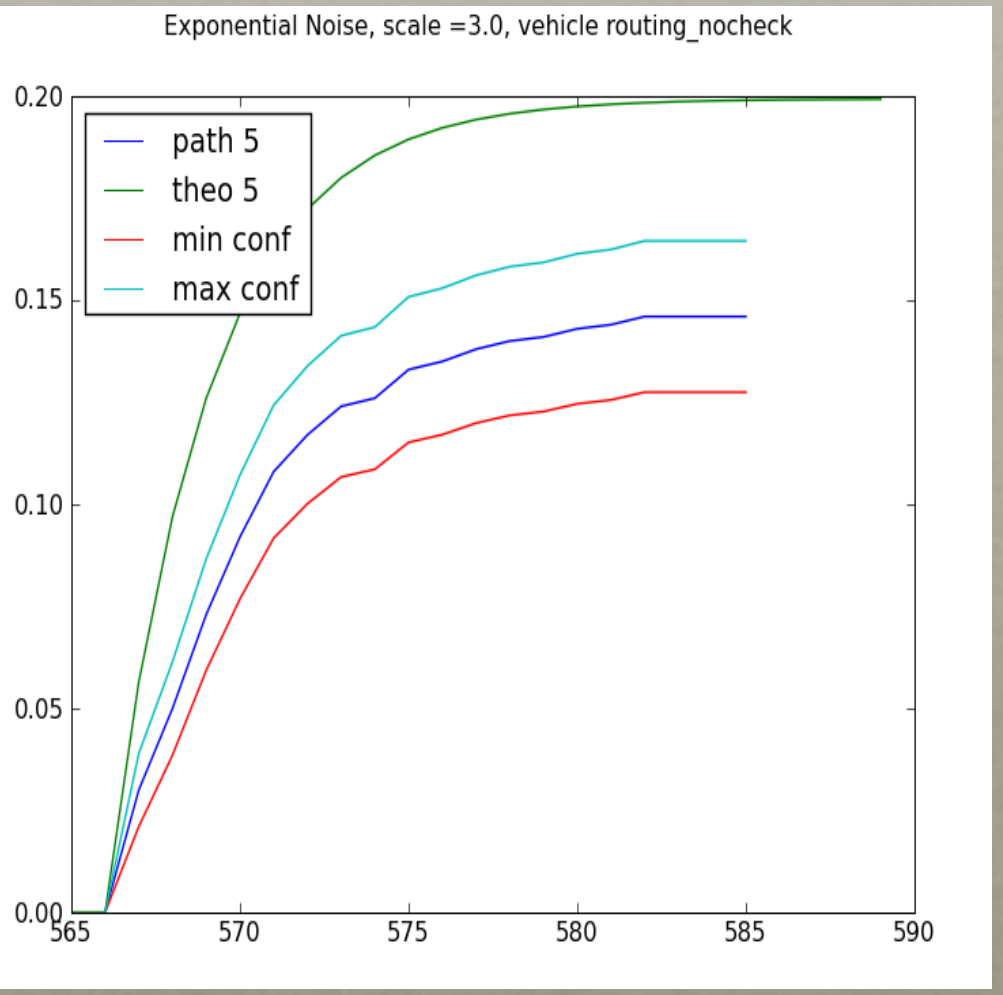
     $\text{Prob}\{t_{n-1,2} \le T \mid t_{0,1} \le t_{0,2} \le t_{1,1} \le t_{1,2} \le \ldots t_{n-1,1} \le t_{n-1,2}\} \le$

     $\text{Prob}\{t_{0,1} \le t_{0,2}\}\ \text{Prob}\{t_{0,2} \le t_{1,1}\}\ \text{Prob}\{t_{1,1} \le t_{1,2}\} \ldots\ \text{Prob}\{t_{n-1,2} \le T\}$

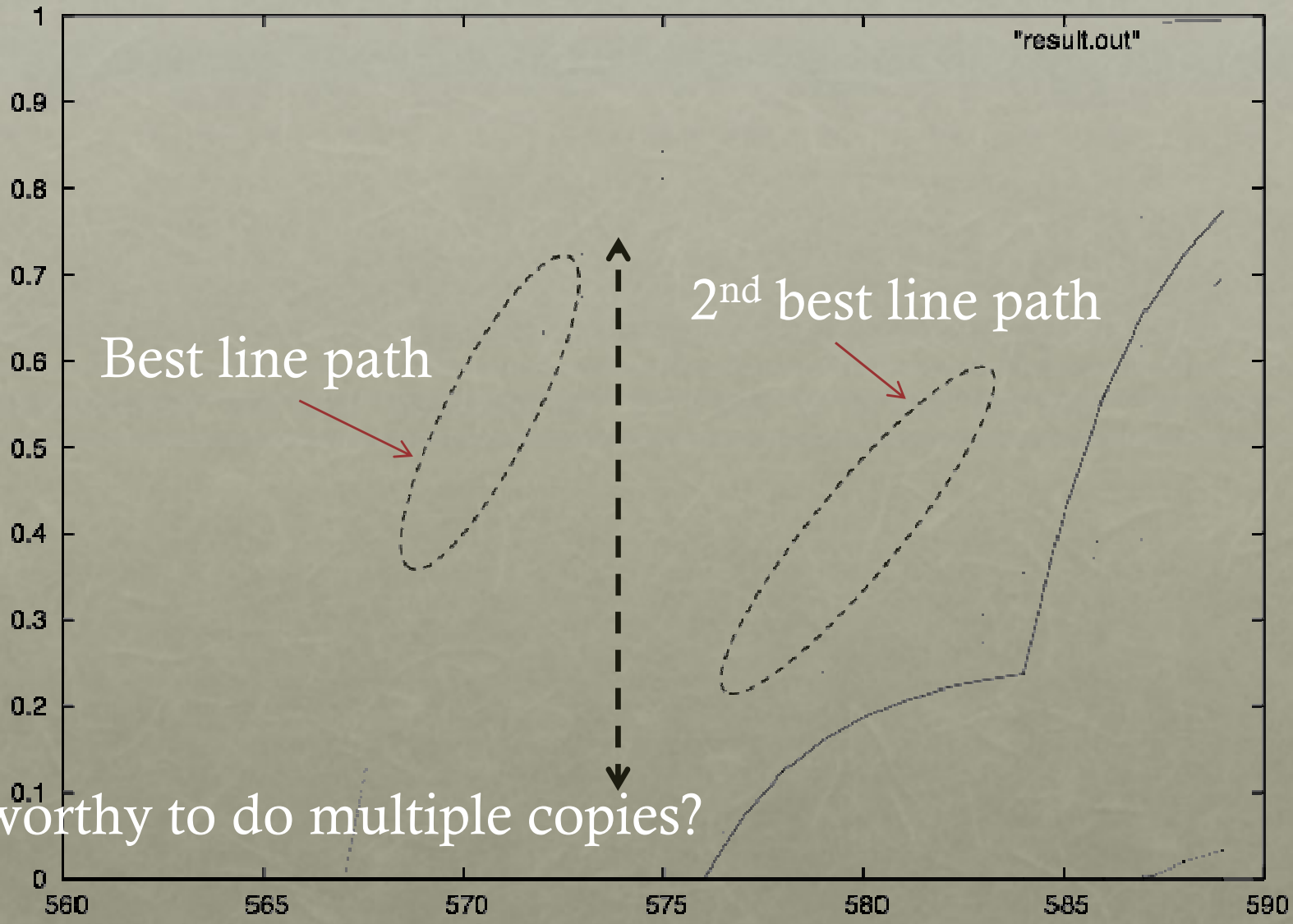
3. Evaluate if it can be useful to do a copy and where

QUALITY OF PROBABILITY DELIVERY ESTIMATION

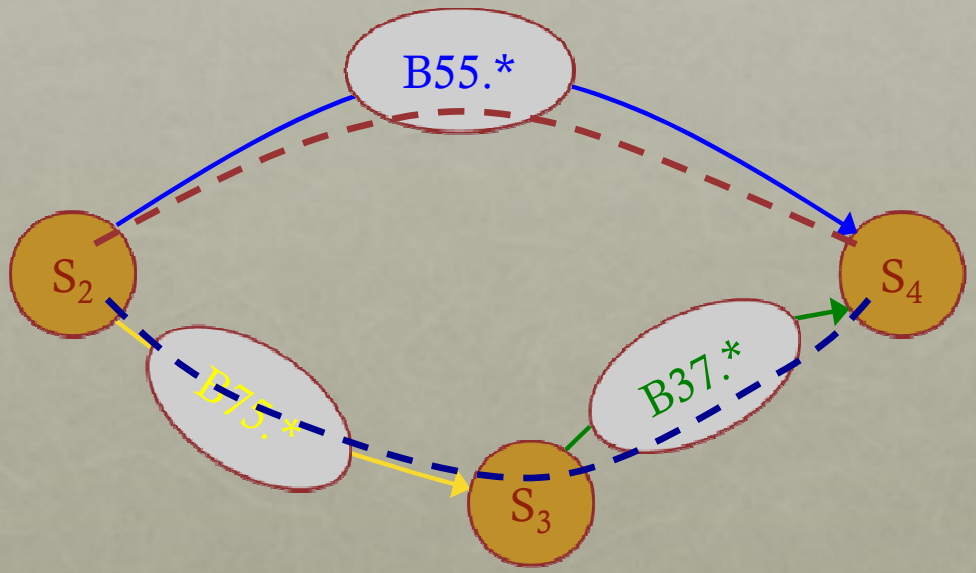




SOME SIMULATION RESULTS ON TURIN NETWORK



A MARKOVIAN MODEL FOR LINE PATH DIFFERENCES



- Packet move along a path described by the state evolution of a Markov process
  - Delivery time is time to absorption
- Determine region of parameters (minimum travel times, connection times, bus frequencies and deadline) such that the second path can be worthy to be exploited
- Check in which region Turin bus network is operating