

Corso di QoS e Sicurezza nelle Reti  
a.a. 2014-2015

Lezione del 8 Giugno 2015

# Summary

- Mobility Generation
- Mobility Analysis and Prediction

# Mobility Generation

Why mobility description is so important in wireless networks and research issues?

The main aim of a mobility model is the 'exact' description of users behavior during their connections with the wireless network.

For example, BS dimensioning, Congestion analysis, Predictions and other activities are not possible if mobility is not described faithfully.

# Mobility Generation

How mobility can be considered [Bhandari]?

- **Trace-based** mobility models: coverage cells “trace” users movements and store data into log-files that can be used a-posteriori;
- **Synthetic** mobility models: a simulator creates users coordinates obeying to some particular laws for speed and acceleration;
- **Geographical patterns**: real roadmaps are considered (like Google maps) and users coordinates are forced to belong only to the possible paths.

[Bhandari]

S. R. Bhandari, G. M. Lee and N. Crespi, “*Mobility Model for User’s Realistic Behavior in Mobile Ad Hoc Network*”, *IEEE Communication Networks and Services Research Conference (CNSR)*.

# Mobility Generation

## TRACE-BASED MOBILITY - EXAMPLE

an example of some syslog entries that were taken from the trace set.

986996241	Apr 11 09:37:21	AcadBldg33AP6	(Info): Station 004096daa8fe Authenticated
986996241	Apr 11 09:37:21	AcadBldg33AP6	(Info): Station 004096daa8fe Associated
986996363	Apr 11 09:39:23	AcadBldg33AP5	(Info): Station 00409630cdc9 roamed
986996363	Apr 11 09:39:23	AcadBldg33AP5	(Info): Station 00409630cdc9 roamed
986996363	Apr 11 09:39:23	AcadBldg33AP6	(Info): Station 00409630cdc9 Authenticated
986996363	Apr 11 09:39:23	AcadBldg33AP6	(Info): Station 00409630cdc9 Reassociated
986996680	Apr 11 09:44:40	AdmBldg19AP3	(Info): Station 0040961e58be Reassociated

Part of a syslog trace collected on April 11th 2001.

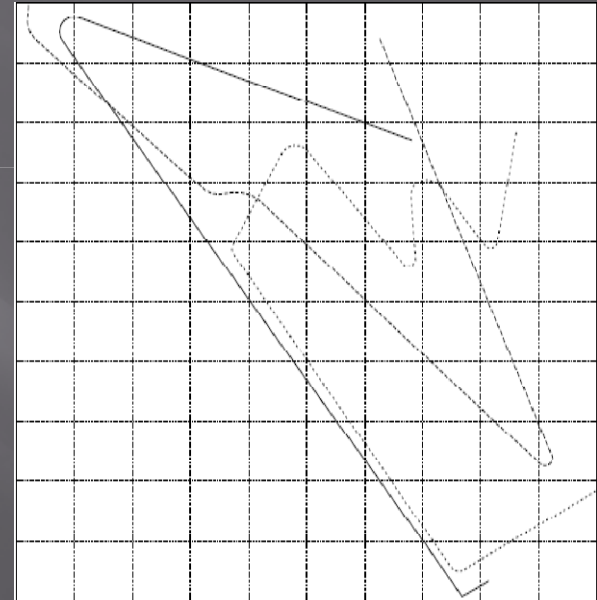
Pro: real user patterns;

Con: need of accessing TLC companies DBs.

# Mobility Generation

## SYNTHETIC MOBILITY – “SOME” EXAMPLES

- Random WayPoint (RWP);
- Markovian (MK);
- Brownian (BR);
- Smooth Random (SR);



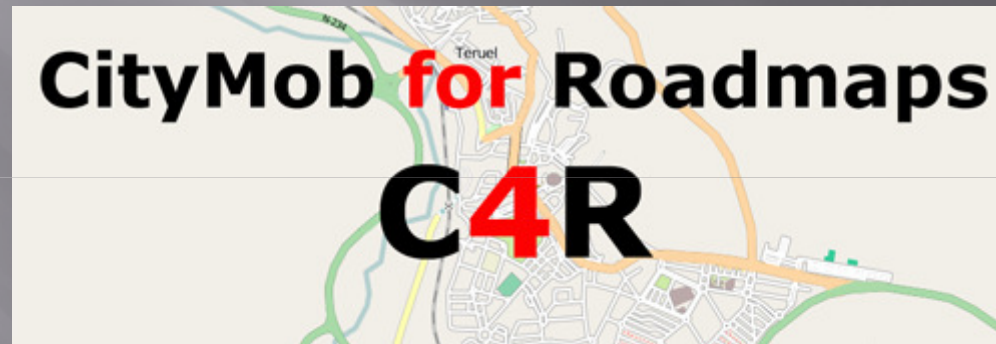
Pro: analytical expressions available;

Con: real environments cannot be considered.

# Mobility Generation

## GEOGRAPHICAL PATTERNS – EXAMPLE

### City 4 Roadmaps [Martinez]



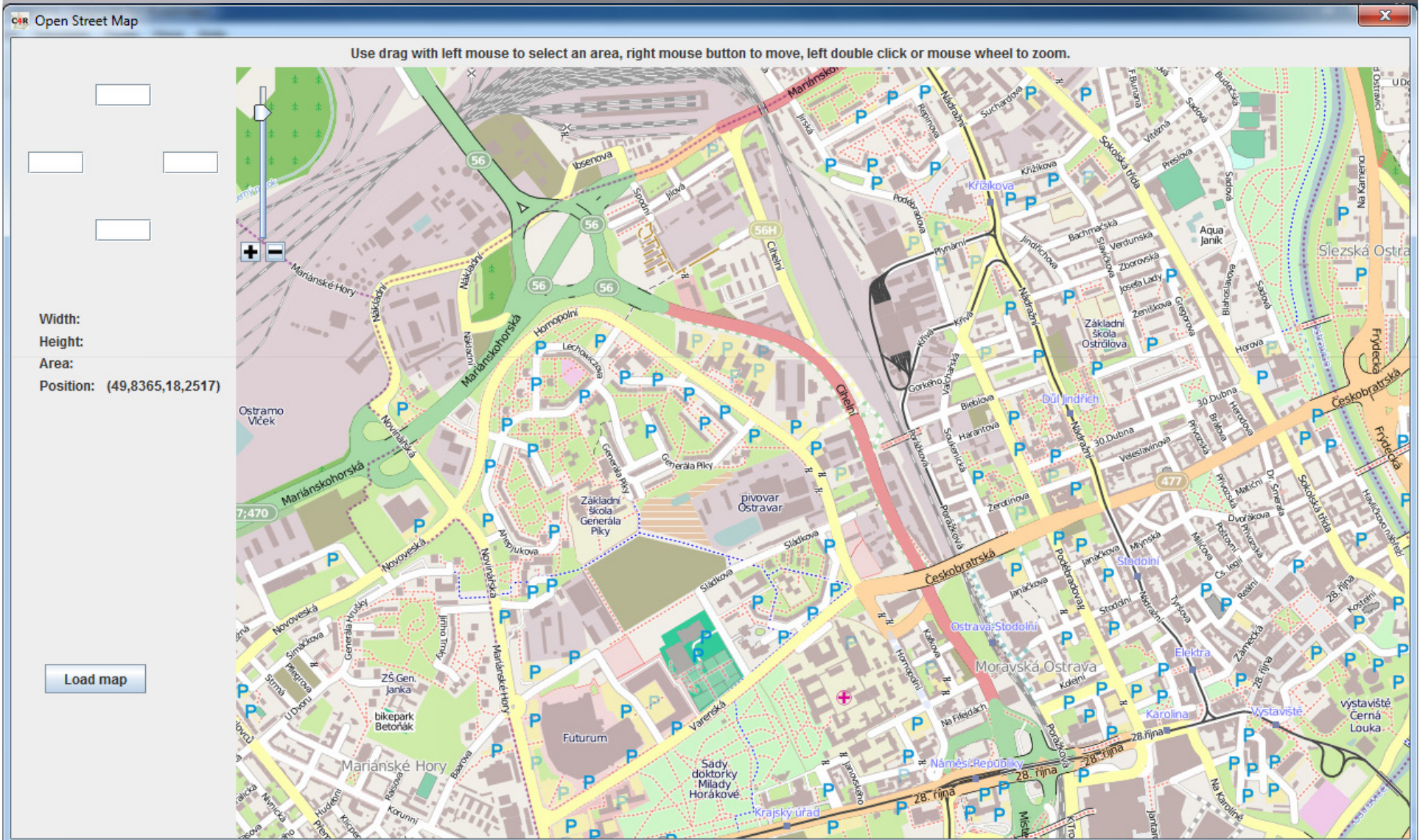
It is a mobility generator software based on real roads ([www.openstreetmap.org](http://www.openstreetmap.org)), which can be chosen for the considered coverage area.

[Martinez]

Martinez, F.J., Cano, J.-C., Calafate, C.T., Manzoni, P., “CityMob: A Mobility Model Pattern Generator for VANETs”, IEEE ICC Workshops.

# Mobility Generation

## GEOGRAPHICAL PATTERNS - EXAMPLE

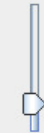


# Mobility Generation

## GEOGRAPHICAL PATTERNS - EXAMPLE

ostrava - Citymob for Roadmaps

File Simulate Tools View Help



Wizard progress

Step 3 of 5

This panel allows you to add random vehicles in the network. The vehicles will be deployed in the whole network according to the existing downtowns weight.

There are three parameters. The first one "Vehicles number" is the number of random vehicles that will be deployed. The second parameter "Downtown Rate" is the rate of vehicles that will be deployed in the downtown. This parameter must be between 0 and 1. 0 means that the vehicles will be deployed uniformly in the whole network and 1 means that all the vehicles will be deployed in the different downtowns. Finally, the third parameter is the random vehicles departure time in the simulation.

If you do not want to add random vehicles just click "Next".

Vehicles Number

Downtown Rate

Departure (s.)

Position (2.041,67,-42)

< Back

Next >

Cancel

# Mobility Generation

## GEOGRAPHICAL PATTERNS - EXAMPLE

ostrava - Citymob for Roadmaps

File Simulate Tools View Help



Wizard progress

Step 4 of 5

Please, select a mobility model

- Krauß modified (default)
- Krauß
- P. Wagner 2009
- Kerner
- IDM

Acceleration (m/s<sup>2</sup>)

Deceleration (m/s<sup>2</sup>)

Sigma

Tau (s.)

The Krauß model with some modifications which is the default model used in SUMO. Click on the links below for further information.

[Krauss\\_1998\\_1](#)

[Krauss\\_1998\\_2](#)

Position (1.633,33,-264,22)

< Back

Next >

Cancel

# Mobility Generation

## GEOGRAPHICAL PATTERNS - EXAMPLE

ostrava\_1.tcl - Blocco note

File Modifica Formato Visualizza ?

```
# # This file was parsed with Citymob for Roadmaps (C4R) version 1.0#
#Node 0 = random_undefined_0_0$node_(0) set X_ 2094.08$node_(0) set Y_ 476.42$node_(0) set Z_ 0.0
#Node 1 = random_undefined_1_0$node_(1) set X_ 2354.33$node_(1) set Y_ 310.05$node_(1) set Z_ 0.0
#Node 2 = random_undefined_2_0$node_(2) set X_ 99.87$node_(2) set Y_ 587.89$node_(2) set Z_ 0.0
#Node 3 = random_undefined_3_0$node_(3) set X_ 2363.95$node_(3) set Y_ 307.37$node_(3) set Z_ 0.0
#Node 4 = random_undefined_4_0$node_(4) set X_ 2345.17$node_(4) set Y_ 949.64$node_(4) set Z_ 0.0
#Node 5 = random_undefined_5_0$node_(5) set X_ 282.65$node_(5) set Y_ 817.64$node_(5) set Z_ 0.0
#Node 6 = random_undefined_6_0$node_(6) set X_ 1758.46$node_(6) set Y_ 577.04$node_(6) set Z_ 0.0
#Node 7 = random_undefined_7_0$node_(7) set X_ 2183.79$node_(7) set Y_ 502.41$node_(7) set Z_ 0.0
#Node 8 = random_undefined_8_0$node_(8) set X_ 269.04$node_(8) set Y_ 803.35$node_(8) set Z_ 0.0
#Node 9 = random_undefined_9_0$node_(9) set X_ 118.54$node_(9) set Y_ 128.36$node_(9) set Z_ 0.0
#Path $node_(0) = random_undefined_0_0$ns_ at 0.0 "$node_(0) setdest 2093.740012487098 477.4556198583798 1.0899999999999674"$ns_ at 1.0 "$node_(0) setdest 20
t 2073.5232046030173 545.5244995463597 15.01581858386642"$ns_ at 12.0 "$node_(0) setdest 2066.7166037104716 549.5737691458795 7.9199999999999944"$ns_ at 13.0
ns_ at 23.0 "$node_(0) setdest 1979.7939197180392 541.0197552749157 6.9900000000000066"$ns_ at 24.0 "$node_(0) setdest 1972.0109689989022 538.6697386572117 8.
.71697822571014 17.22038139989768"$ns_ at 35.0 "$node_(0) setdest 1840.9346256293325 499.27201249728455 8.219884391967515"$ns_ at 36.0 "$node_(0) setdest 183
"$node_(0) setdest 1711.9689382602492 462.8689889286944 9.519999999999843"$ns_ at 47.0 "$node_(0) setdest 1704.8219968849603 460.4978860253633 7.530000000000
585 10.660000000000029"$ns_ at 58.0 "$node_(0) setdest 1609.4868781720213 424.446768821255 19.673592572248943"$ns_ at 59.0 "$node_(0) setdest 1590.1630372963
setdest 1462.0612339239644 369.06211928455133 14.246403258255244"$ns_ at 70.0 "$node_(0) setdest 1449.4070148702365 363.9441860942618 13.649999999999996"$ns_
5000000000135"$ns_ at 81.0 "$node_(0) setdest 1307.7203504884594 318.6626662232337 13.809999999999915"$ns_ at 82.0 "$node_(0) setdest 1294.5179664531222 31
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42 13.450000000000005"$ns_ at 104.0 "$node_(0) setdest 1005.9500428208664 172.8008608331129 23.200025551125457"$ns_ at 105.0 "$node_(0) setdest 995.395609677
st 888.7688165944278 80.23735063785132 13.719999999999972"$ns_ at 116.0 "$node_(0) setdest 878.0410013192026 71.7648728762608 13.670000000000006"$ns_ at 117.0
9999971"$ns_ at 127.0 "$node_(0) setdest 794.8908058826796 189.70986244735175 13.849999999999982"$ns_ at 128.0 "$node_(0) setdest 783.9966784580314 209.99621
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2307.9286648654397 247.5259645679489 8.150000000000023"$ns_ at 12.0 "$node_(1) setdest 2313.369721460062 241.53906193519177 8.089999999999982"$ns_ at 13.0 "$n
"$ns_ at 23.0 "$node_(1) setdest 2295.4450095081106 186.5508916712744 5.637324224248126"$ns_ at 24.0 "$node_(1) setdest 2288.9046480278694 181.857686827271 8
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```

sabato 3 novembre 2012

# Mobility Generation

Once the patterns coordinates have been created, they can be used for the desired purposes. In our fields of research, mobility patterns have to be **analyzed** accurately.

# Summary

- QoS in Telecommunication Systems
- Wireless Communications and Issues
- Wireless Channel Modeling
- Bandwidth Management
- Mobility Generation
- Mobility Analysis and Prediction
- Some Reachable Results and Conclusions
- Research Group Description

# Mobility Analysis and Prediction

Let us recall what previously exposed:

## Bandwidth Management

### Passive Reservation Issues

- 1) First of all, **the time spent in each cell** has to be considered (Cell Stay Time - CST);
- 2) The **number of hand-over events** has to be evaluated, so the coverage network can know how many cells a mobile host will visit;
- 3) For 2D scenarios, the **exact cells** that a mobile host will visit need to be identified.

Let us see how mobility can be “generated” and, then, analyzed.

How can the CST be evaluated?

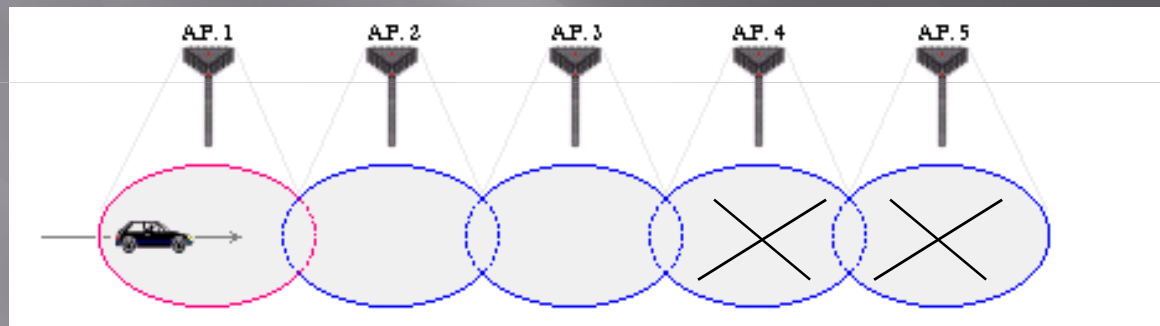
How can the number of h.o. be evaluated?

What cells will a mobile host visit?

# Mobility Analysis and Prediction

## How to evaluate the CST

**Mono-dimensional** case: depending on its mobility characteristics, a single user may not visit all the cells of the system:



CST can be evaluated by observing users mobility through simulations campaigns, considering the time spent by a single user under a cell coverage area.

# Mobility Analysis and Prediction

How to evaluate the CST - simulation campaigns

Mono-dimensional case: for each cell of the system the hand-in arrival and hand-out departure times are stored.

cstAP_MDP - Blocco note		
File	Modifica	Formato
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Cell 1

cstAP_MDP - Blocco note			
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cstAP_MDP - Blocco note			
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Cell 4

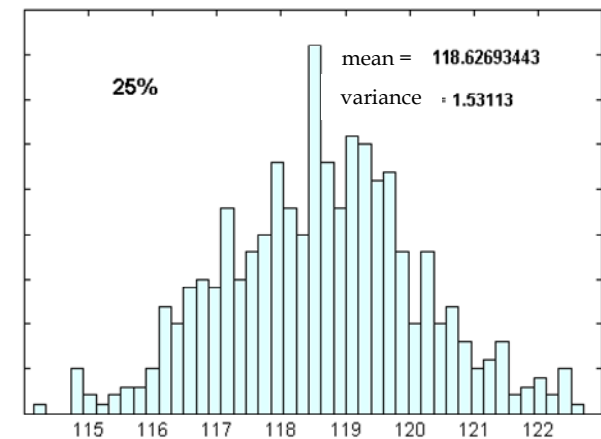
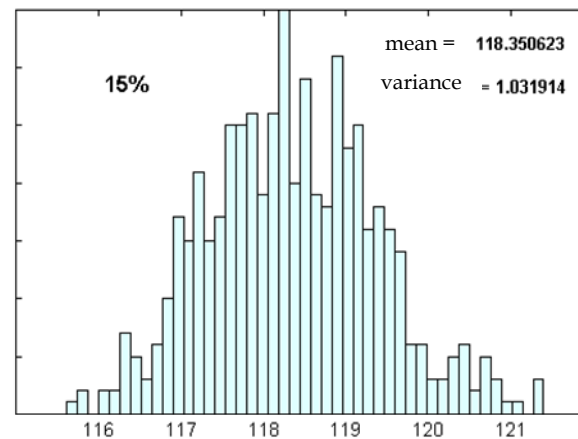
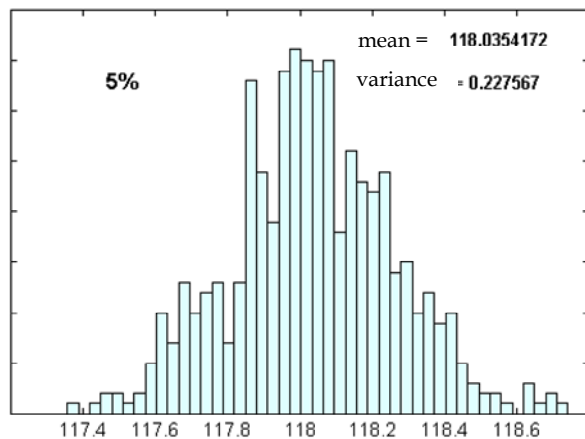
cstAP_MDP - Blocco note			
File	Modifica	Formato	V
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27. 933538,			
26. 679553,			
27. 744573,			
28. 600314,			
28. 046060,			
26. 472494,			
27. 947399,			
26. 957908,			
27. 094909,			
28. 447129,			
27. 465572,			
28. 539498,			
27. 610012,			
26. 351695,			
27. 349512,			
27. 528928,			
26. 565645,			
27. 312175,			
27. 350410,			
27. 136652,			

Cell 5

# Mobility Analysis and Prediction

How to evaluate the CST - simulation campaigns

**Mono-dimensional** case: for each run of simulation campaigns the obtained results are averaged.



GAUSSIAN DISTRIBUTIONS CAN BE CONSIDERED!

# Mobility Analysis and Prediction

How to evaluate the CST - simulation campaigns

The number of cells that a user will probably visit can be evaluated as follows:

$$C_p = \left[ \frac{T_{CHT}}{T_{CST}} \right]$$

$$f(x) = \frac{1}{\mu} e^{-\frac{x}{\mu}}$$

Exponential distribution  
(from literature)

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Gaussian distribution

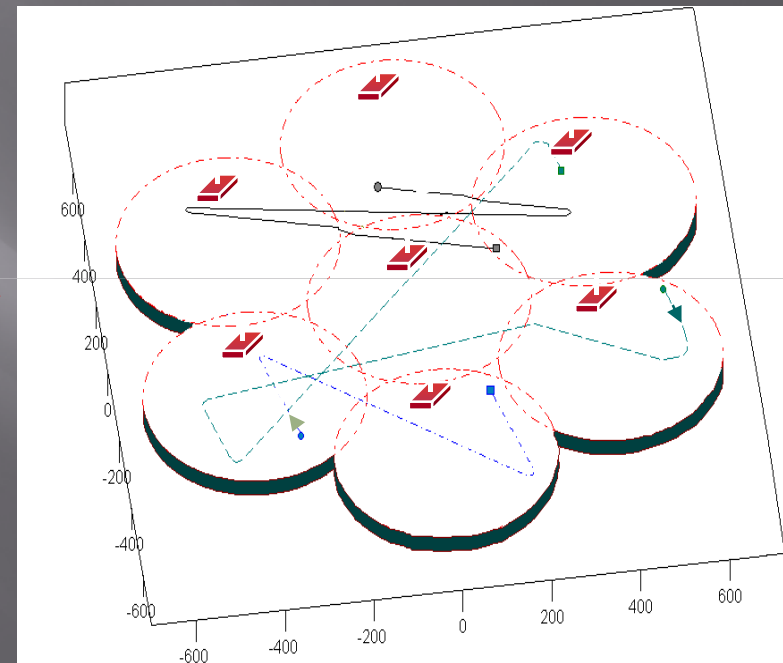
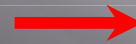
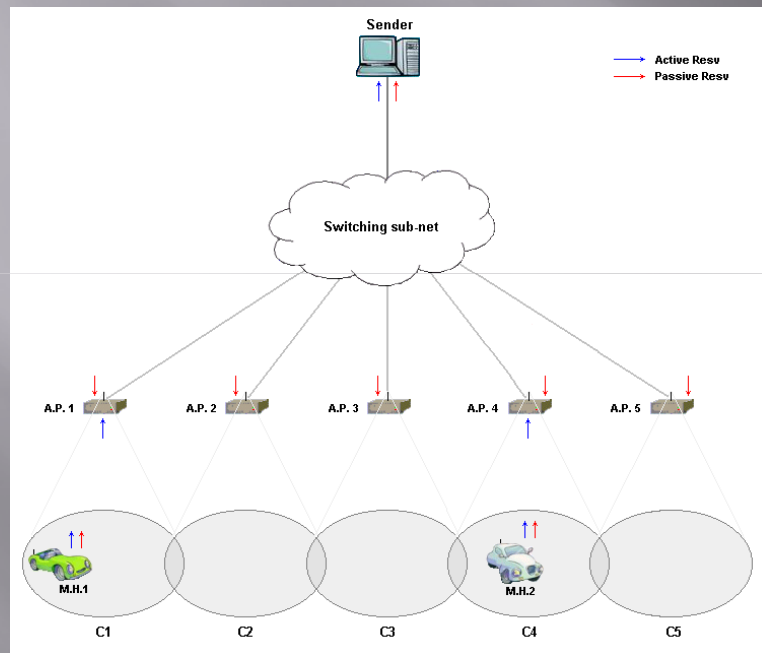
The value of  $C_p$  is used only for a quantitative purpose and the assumption of a CST normally distributed has been verified through a KS-test.

**WHAT ABOUT 2D ENVIRONMENT?**

# Mobility Analysis and Prediction

## From 1D to 2D

Let us now consider real scenarios (2D):

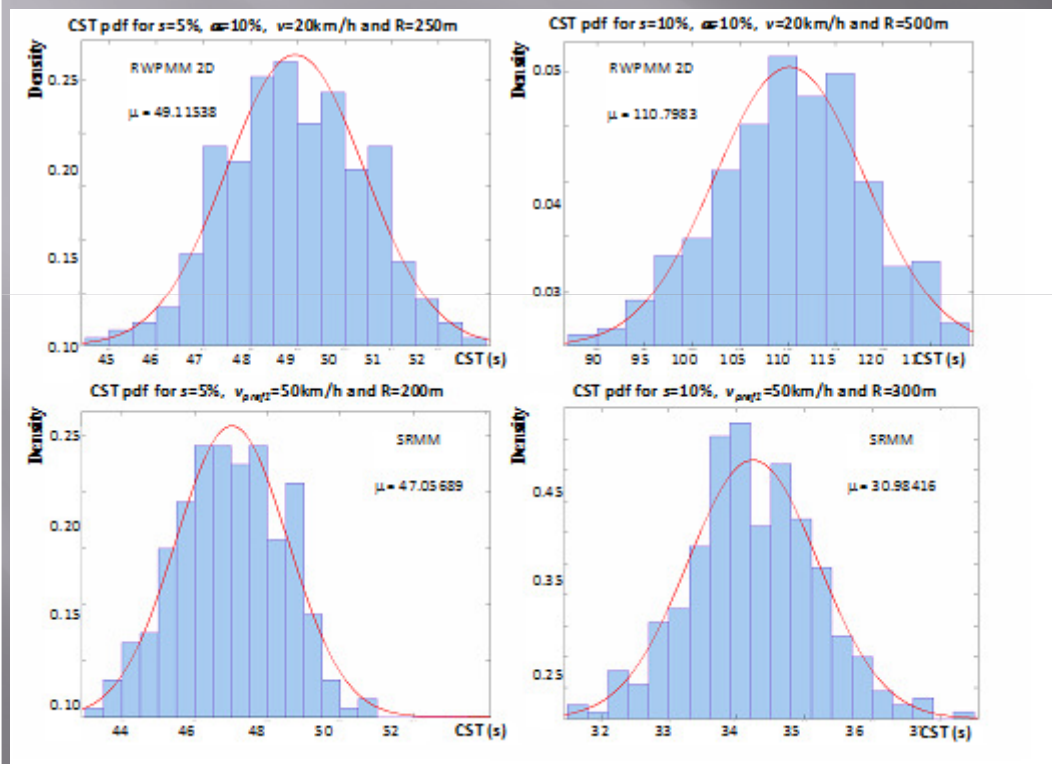


Are there new issues?

# Mobility Analysis and Prediction

## From 1D to 2D

Other simulation campaigns have been carried out in order to evaluate **CST** distribution.



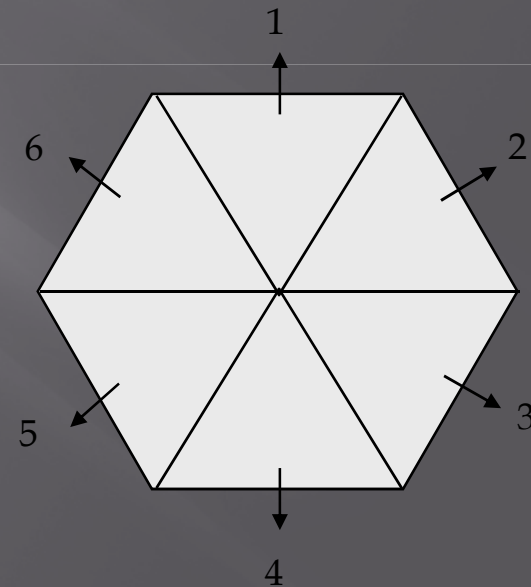
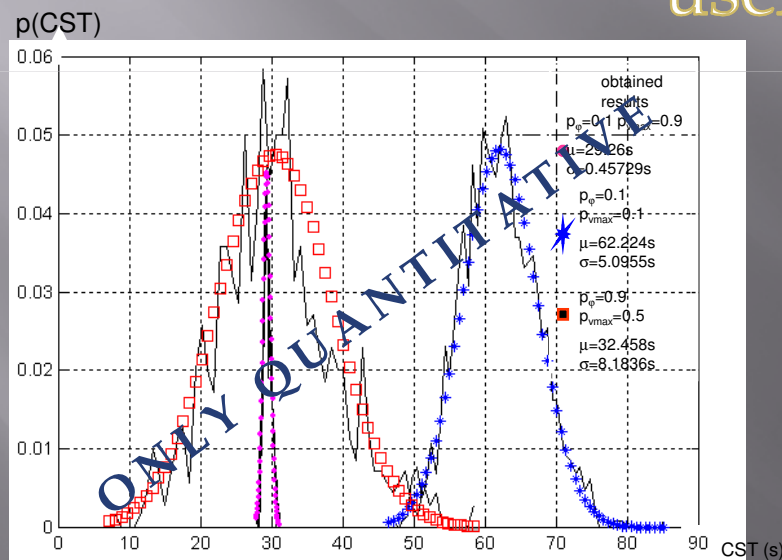
The same considerations of the previous case (1D) can be made for 2D models (like RWP and SR). The hypothesis of Gaussian distribution is still valid.

## What is the new issue?

# Mobility Analysis and Prediction

## From 1D to 2D

The CST knowledge is not enough for users description in a 2D environment, because it gives **only a quantitative** knowledge of the number of cells that a user will visit.

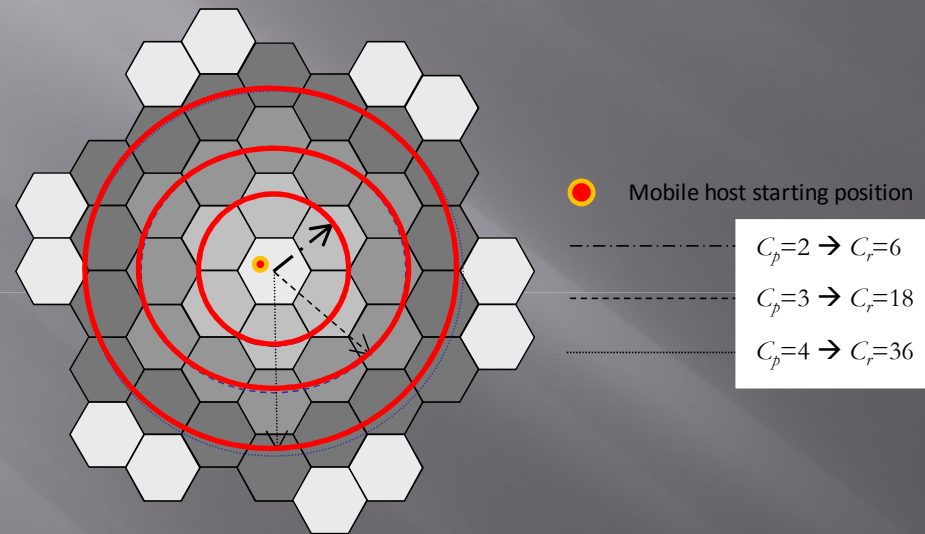


The possibly preferred movement directions of users must be taken into account, so a **qualitative** analysis becomes feasible.

# Mobility Analysis and Prediction

## From 1D to 2D

WHY QUALITATIVE ANALYSIS IS NEEDED IN 2D?



$$C_r = 3 \cdot C_p \cdot (C_p - 1)$$

The number of cells on which the reservations must be made increases in polynomial way, following the illustrated rule: the bandwidth wastage is not negligible (for  $C_p=5$  we have  $C_r=60!!!$ ).

# Mobility Analysis and Prediction

## From 1D to 2D

WHY QUALITATIVE ANALYSIS IS NEEDED IN 2D?



The number of passive reservations is drastically reduced because the circular reservation is not needed now, since directional information is available.

BUT, HOW CAN DIRECTIONAL BEHAVIOR BE ACCOUNTED FOR?

# Mobility Analysis and Prediction

## DIRECTIONAL ANALYSIS IN 2D SCENARIOS

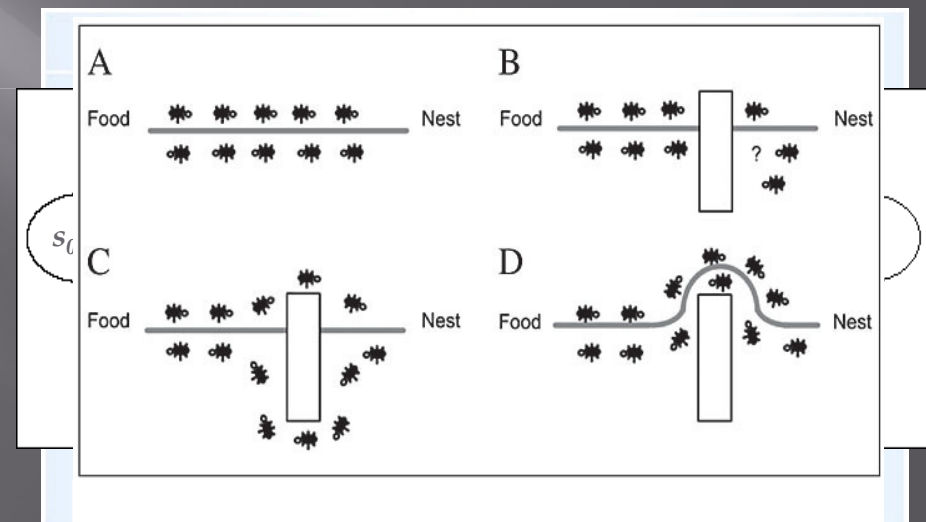
There are many works in literature which use many “tools” to account for directional behaviors:

NEURAL NETWORKS

MARKOV CHAINS

SWARM

INTELLIGENCE

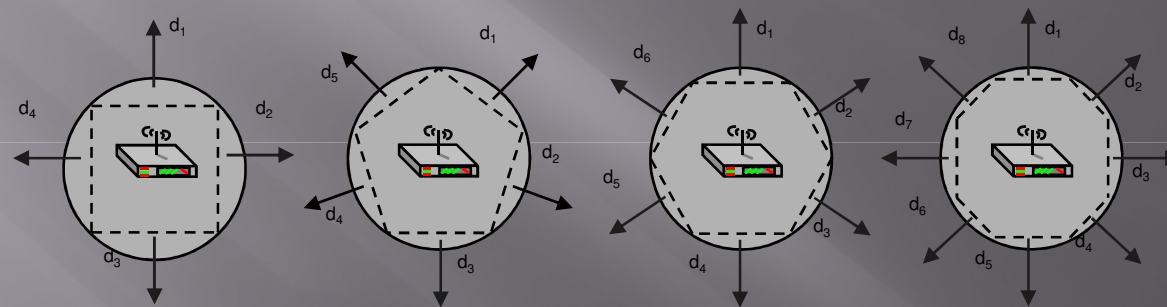


ANALYTICAL AND STATISTICAL TOOLS

# Mobility Analysis and Prediction

## A PRACTICAL EXAMPLE

Coverage areas can be approximated through n-side regular polygons and n directions can be considered:



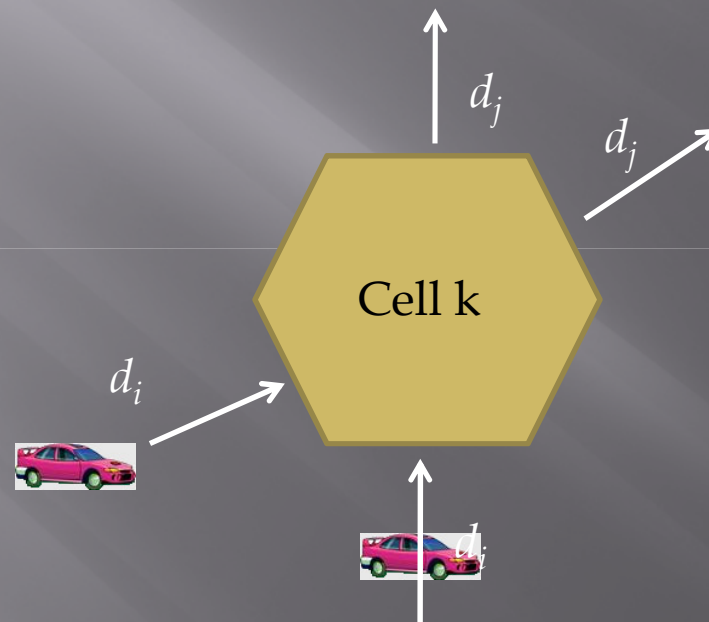
Then a  $n \times n$  matrix can be considered, where the rows indicate the hand-in directions and the columns the hand-out directions; the elements are defined as:

$$M(x,y) = p_{x,y} = P_{cMIP}(x,y) = p(\text{out to } y \in S_{b0} \text{ } t=t_0 + CST / \text{in from } x \in S_{b0} \text{ } t=t_0)$$

# Mobility Analysis and Prediction

## A PRACTICAL EXAMPLE (n=6)

How the elements of the matrix  $M$  can be obtained?



$$M_k(i, j) = \frac{\text{Number\_of\_handins\_from\_}d_i\text{\_and\_handout\_to\_}d_j}{\text{Number\_of\_total\_handins\_from\_}d_i}$$

All the elements are averaged on the number of mobile host

# Mobility Analysis and Prediction

## A PRACTICAL EXAMPLE (n=6)



	1	2	3	4	5	6
1	0.0137	0.0244	0.2779	0.3663	0.3034	0.0256
2	0.0325	0.0132	0.0399	0.3700	0.5056	0.0549
3	0.3708	0.0430	0.0125	0.0316	0.0521	0.5054
4	0.3692	0.2798	0.0249	0.0129	0.0248	0.2994
5	0.3743	0.5094	0.0440	0.0328	0.0127	0.0437
6	0.0318	0.0426	0.5094	0.3769	0.0427	0.0145



$$M(5,2)=0.5094$$

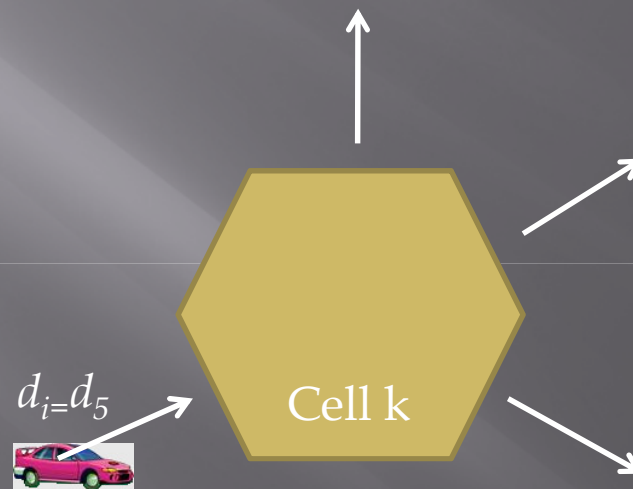
All the elements are averaged on the number of mobile host

# Mobility Analysis and Prediction

A PRACTICAL EXAMPLE (n=6)

HOW TO USE THE MATRIX

	1	2	3	4	5	6
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6	0.0318	0.0426	0.5094	0.3769	0.0427	0.0145



HOW MANY NEIGHBORS DO WE WANT TO CONSIDER?

1 → Reserve on next cell on direction  $d_2$

2 → Reserve on next cells on directions  $d_2$  and  $d_1$

3 → Reserve on next cells on directions  $d_2, d_1$  and  $d_3$

# Mobility Analysis and Prediction

A PRACTICAL EXAMPLE (n=6)

HOW TO USE THE MATRIX

