

Quality of Service and Bandwidth Management Issues in Wireless Networks with Mobile Hosts

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Executive 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

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QoS in Telecommunication Systems

- What are the needs for a remote communication among a source and a destination?



It depends on the specific application
(e.g. *VoIP* or *FTP*)

QoS in Telecommunication Systems

Quality of Service (QoS)

A composition of system performance metrics

Throughput - Effective data transfer rate

Packet Loss - Queue overflows at routers

Delay - Source-to-destination time

Jitter - Delay variation

Availability/Continuity - Ideally, %100 of the time

QoS in Telecommunication Systems

The main goal of QoS is the improvement of network services perceived by applications;

1. Varied sensitivities of network data types

Traffic type	Sensitivities			
	Bandwidth	Loss	Delay	Jitter
Voice	Very low	Medium	High	High
E-commerce	Low	High	High	Low
Transactions	Low	High	High	Low
E-mail	Low	High	Low	Low
Telnet	Low	High	Medium	Low
Casual browsing	Low	Medium	Medium	Low
Serious browsing	Medium	High	High	Low
File transfers	High	Medium	Low	Low
Video conferencing	High	Medium	High	High
Multicasting	High	High	High	High

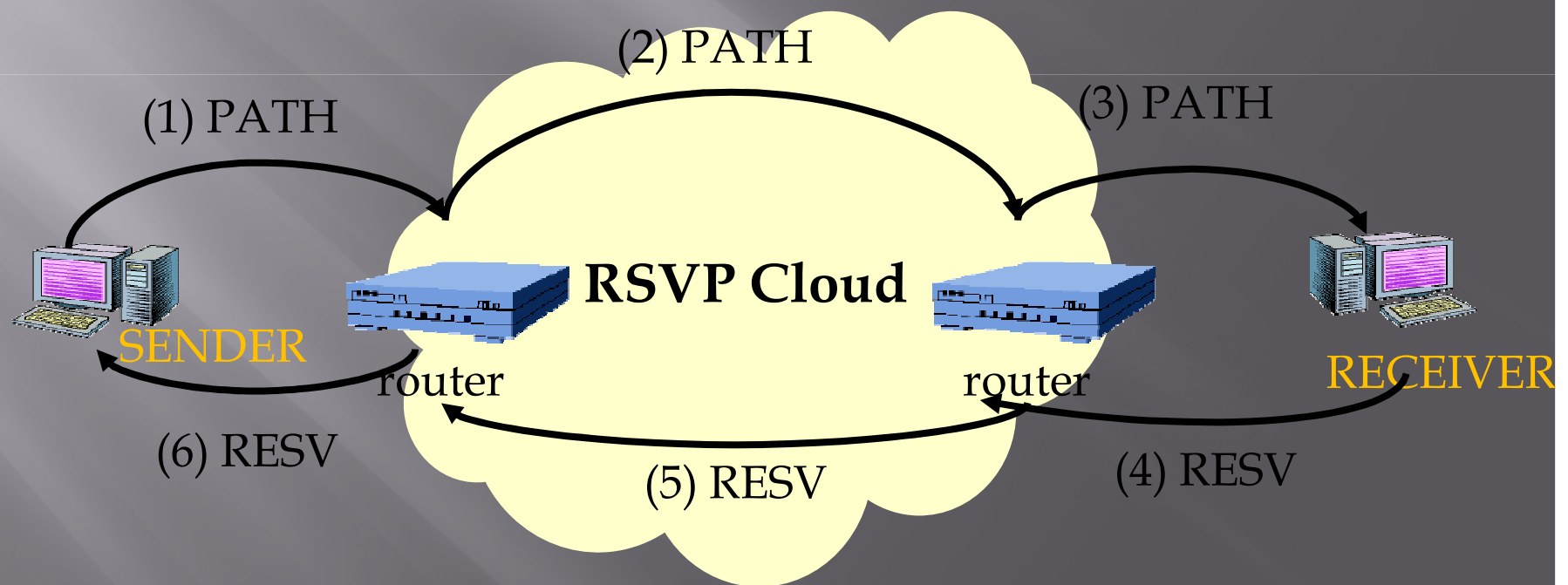
* Complex contents may include audio and video clips and fast animations.

Source: CQOS Inc.

QoS needs depend on the considered application:

QoS in Telecommunication Systems

In wired scenario many efforts have been made in order to provide QoS and ReSerVation Protocol (RSVP) is an example of QoS management protocol for Integrated Services:



QoS in Telecommunication Systems

But, what about

QoS in wireless networks with
mobile hosts

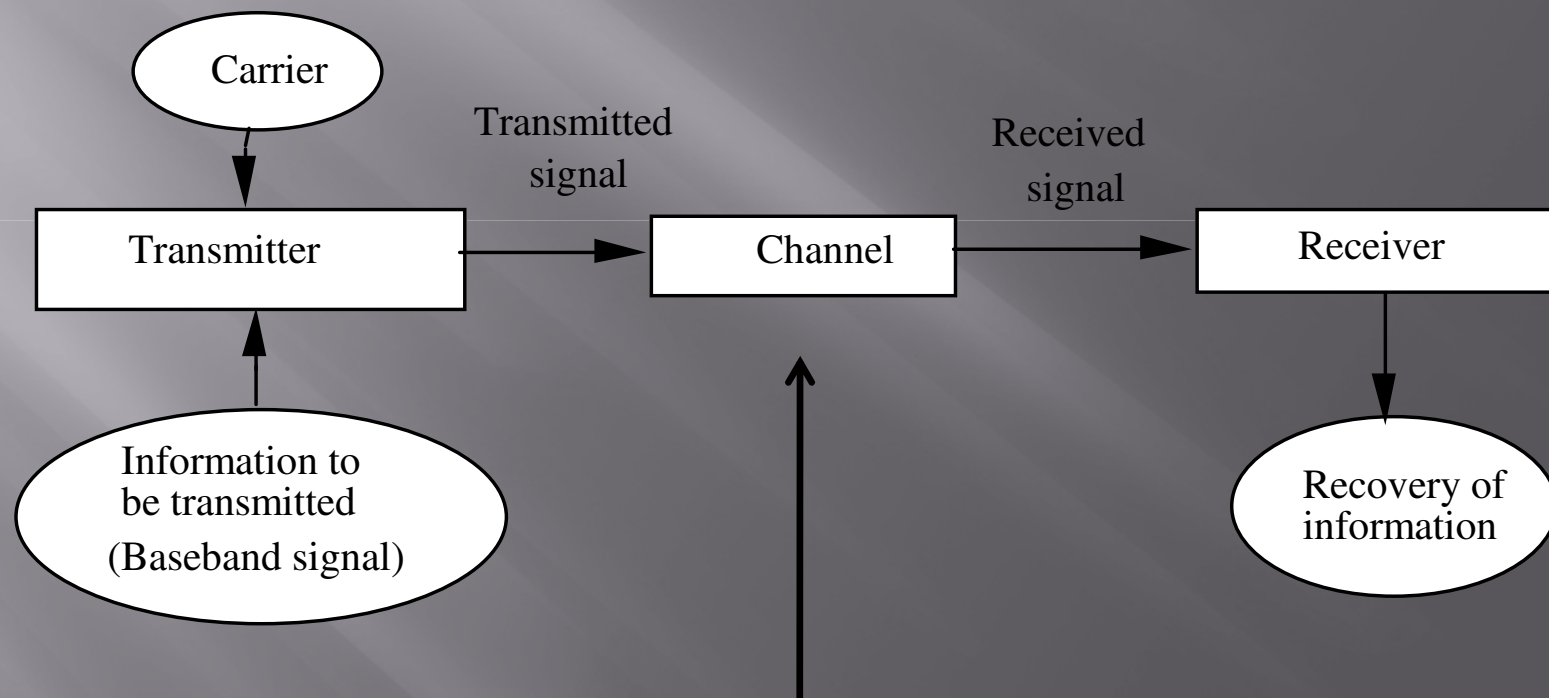


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Wireless Communications and Issues

Wireless networks provide connectivity without using any cable:



NO WIRED CONNECTIONS ARE NEEDED!

Wireless Communications and Issues

Examples of current available technologies:

Cellular systems

Wireless LANs

Satellite Systems

WiMAX

Bluetooth

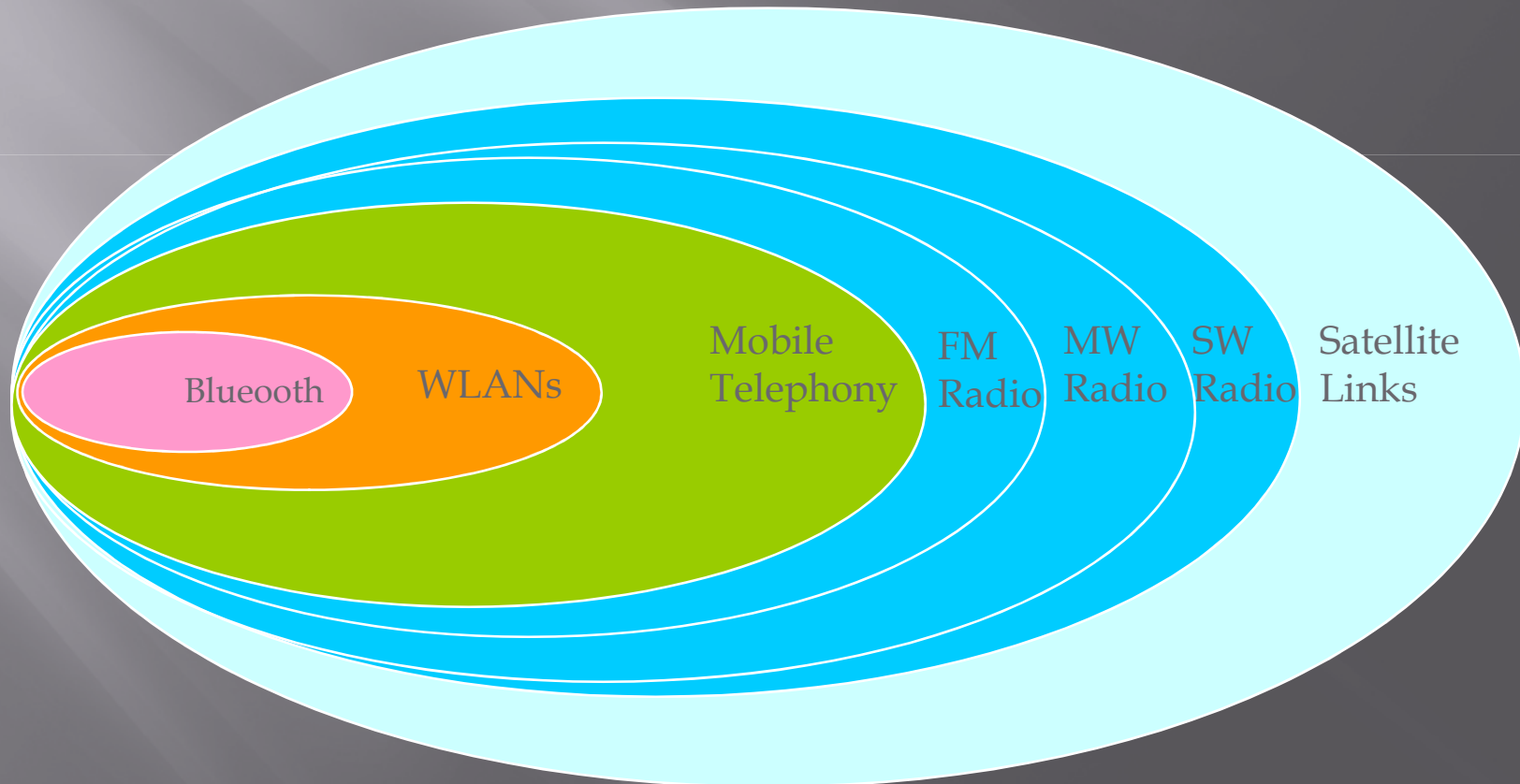
UltraWideBand (UWB) Radios

Zigbee Radios

Wireless Communications and Issues

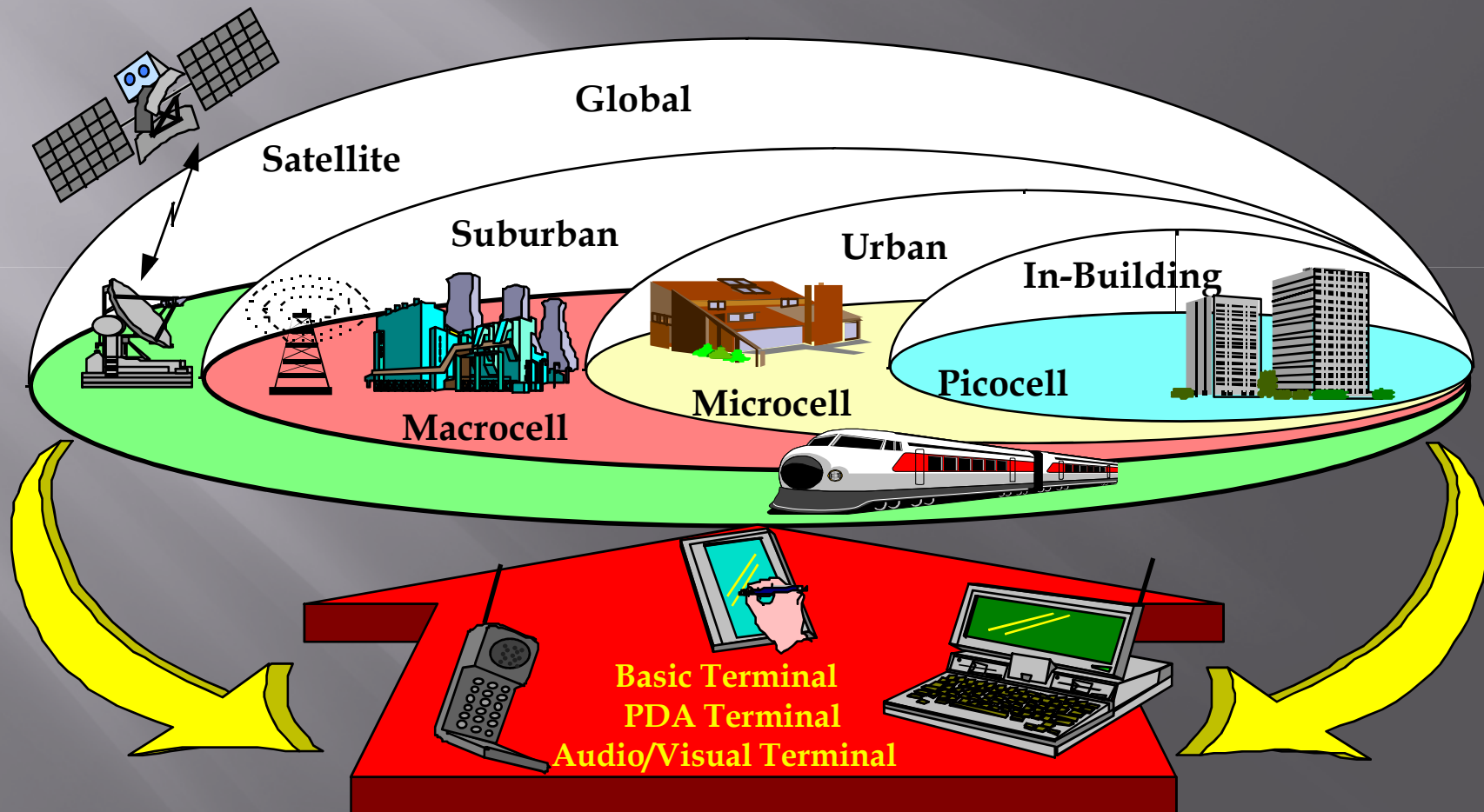
RANGE COMPARISON

1 m 10 m 100 m 1 Km 10 Km 100 Km 1,000 Km



Wireless Communications and Issues

COVERAGE CELL EXAMPLES



Wireless Communications and Issues

Advantages

- Flexibility;
- Easy deployment and low costs;
- Introduction of user mobility.

Disadvantages:

- Use of **RF waves** (path-loss and fading);
- Higher interference (lower throughput);
- **Hand-over** management is mandatory.

Wireless Communications and Issues

The main issues are:

- Service degradations introduced by the **non-ideality of the wireless channel** (also related to mobility effects);
- Needing of **hand-over management** when mobile hosts change coverage areas.

***WHAT CAN WE DO TO FACE
THESE PROBLEMS???***

Wireless Communications and Issues

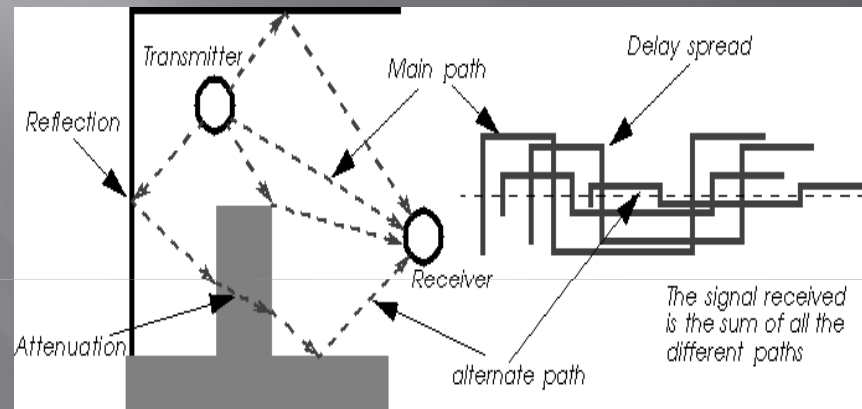
- Wireless link can be accounted-for by an opportune **CHANNEL MODEL**, which is able to describe the stochastic evolution of the link;
- Communication resources (i.e. bandwidth) can be (re)allocated by considering the **LINK QUALITY**;
- Mobility can be analyzed statistically in order to introduce a certain **PREDICTION** degree in resource allocation.

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Wireless Channel Modeling

Time-variant quality of the link and different propagation phenomena: path-loss, reflection, attenuation and fading:



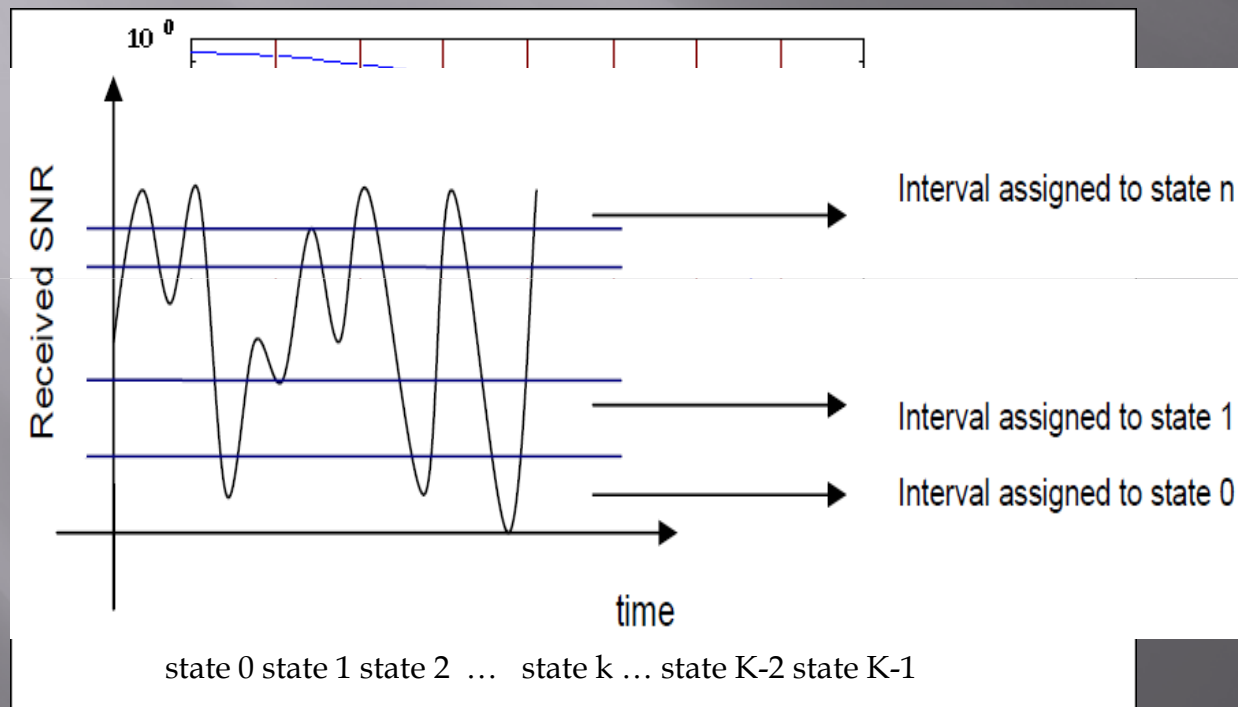
If a single impulse (or any shape) is transmitted many times, the received signal will be different for every experiment;

$$\text{TX} \longrightarrow s(t) = \text{Re} \left[s_l(t) e^{j2\pi f_c t} \right] \xrightarrow{\text{WIRELESS LINK}} x(t) = \sum_n \alpha_n(t) s[t - \tau_n(t)], \text{RX}$$

A **non-deterministic** description of the problem is mandatory in order to model channel evolution: stochastic processes like the discrete-time and finite-state Markovian ones are able to do that.

Wireless Channel Modeling

The SNR range is partitioned into a set of K ranges and K states of the Markov model SNR associated to each of them:

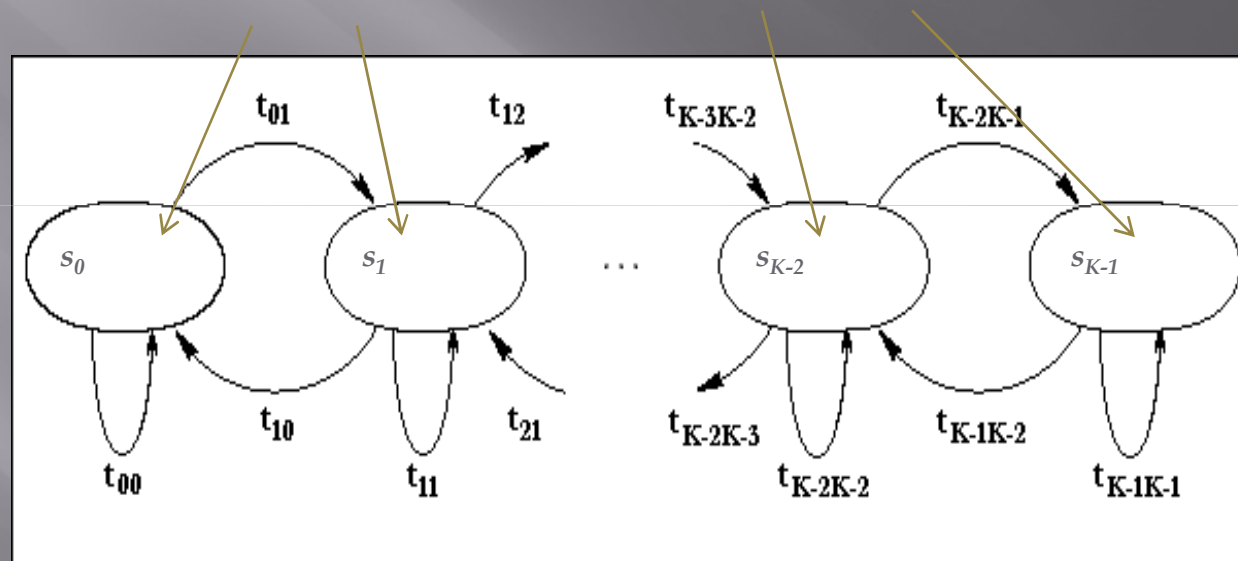


PARTITIONING

[Wang-Moayeri] H. S. Wang, N. M. Moayeri, "Finite-State Markov Channel – A useful model for radio communication channels", *IEEE Trans. Vehic. Tech.*

Wireless Channel Modeling

In this way, the discretized model describes the evolution of the link during time:



state 0 state 1 state 2 ... state k ... state K-2 state K-1

The model is completely defined by three variables, which must be tuned [KRUNZ]: T , p and e ;

[KRUNZ] M. Hassan, M. Krunz, I. Matta, "Markov-based channel characterization for tractable performance analysis in wireless packet networks", *IEEE Trans. Wireless Comm.*

Wireless Channel Modeling

A practical case of study

Needed hardware and software:

- 2 nodes (notebooks or netbooks for example) configured in ad-hoc mode with two wireless interfaces (we considered 802.11b/g interfaces);
- Windows or Linux operating systems;
- Netstumbler (4.0 or above) and Wireshark.

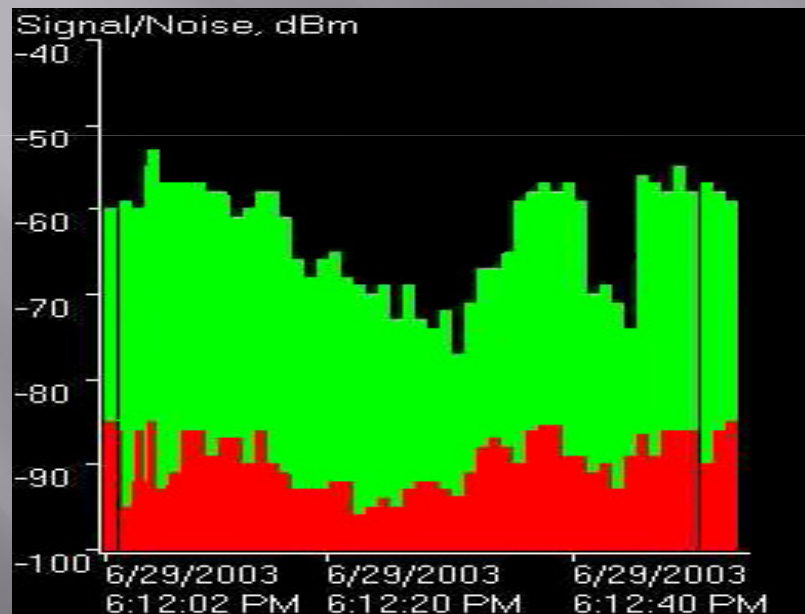
Wireless Channel Modeling

A practical case of study

- What kind of software can we use?

Netstumbler (or Kismet for Linux)

Wireshark (optional)



SNR over the time

No.	Time	Source	Destination	Protocol	Info
1	0.000000	192.168.0.1	192.168.0.2	IP	Fragmented IP protocol (proto=ICMP 0x01, off=0)
2	0.006639	192.168.0.1	192.168.0.2	IP	Fragmented IP protocol (proto=ICMP 0x01, off=1480)
3	0.012179	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
4	0.012222	192.168.0.2	192.168.0.1	IP	Fragmented IP protocol (proto=ICMP 0x01, off=0)
5	0.012240	192.168.0.2	192.168.0.1	IP	Fragmented IP protocol (proto=ICMP 0x01, off=1480)
6	0.012251	192.168.0.2	192.168.0.1	ICMP	Echo (ping) reply
7	0.922909	192.168.0.1	192.168.0.2	IP	Fragmented IP protocol (proto=ICMP 0x01, off=0)
8	0.977295	192.168.0.1	192.168.0.2	IP	Fragmented IP protocol (proto=ICMP 0x01, off=1480)
9	1.000295	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
10	1.000338	192.168.0.2	192.168.0.1	IP	Fragmented IP protocol (proto=ICMP 0x01, off=0)
11	1.000357	192.168.0.2	192.168.0.1	IP	Fragmented IP protocol (proto=ICMP 0x01, off=1480)
12	1.000365	192.168.0.2	192.168.0.1	ICMP	Echo (ping) reply
13	1.857071	192.168.0.1	192.168.0.2	IP	Fragmented IP protocol (proto=ICMP 0x01, off=0)
14	1.863975	192.168.0.1	192.168.0.2	IP	Fragmented IP protocol (proto=ICMP 0x01, off=1480)
15	1.874705	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
16	1.874745	192.168.0.2	192.168.0.1	IP	Fragmented IP protocol (proto=ICMP 0x01, off=0)
17	1.874758	192.168.0.2	192.168.0.1	IP	Fragmented IP protocol (proto=ICMP 0x01, off=1480)
18	1.874765	192.168.0.2	192.168.0.1	ICMP	Echo (ping) reply
19	2.813386	192.168.0.1	192.168.0.2	IP	Fragmented IP protocol (proto=ICMP 0x01, off=0)
20	2.870148	192.168.0.1	192.168.0.2	IP	Fragmented IP protocol (proto=ICMP 0x01, off=1480)

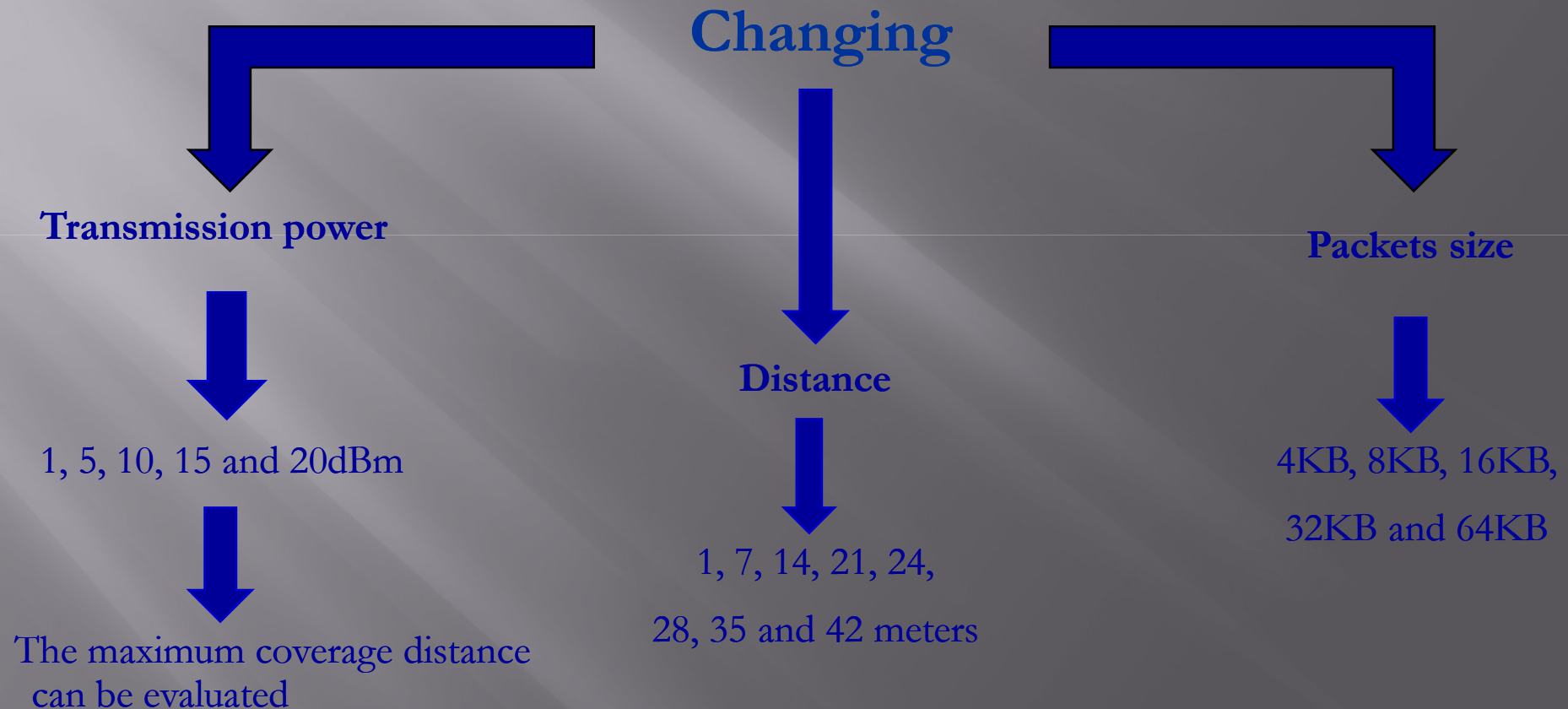
Frame 34 (1514 bytes on wire, 1514 bytes captured)
Ethernet II, Src: AmbitMic_9b:db:49 (00:0e:9b:9b:db:49), Dst: D-Link_64:c5:f9 (00:22:b0:64:c5:f9)
Internet Protocol, Src: 192.168.0.2 (192.168.0.2), Dst: 192.168.0.1 (192.168.0.1)
Data (1480 bytes)

Protocol analyzer

Wireless Channel Modeling

A practical case of study

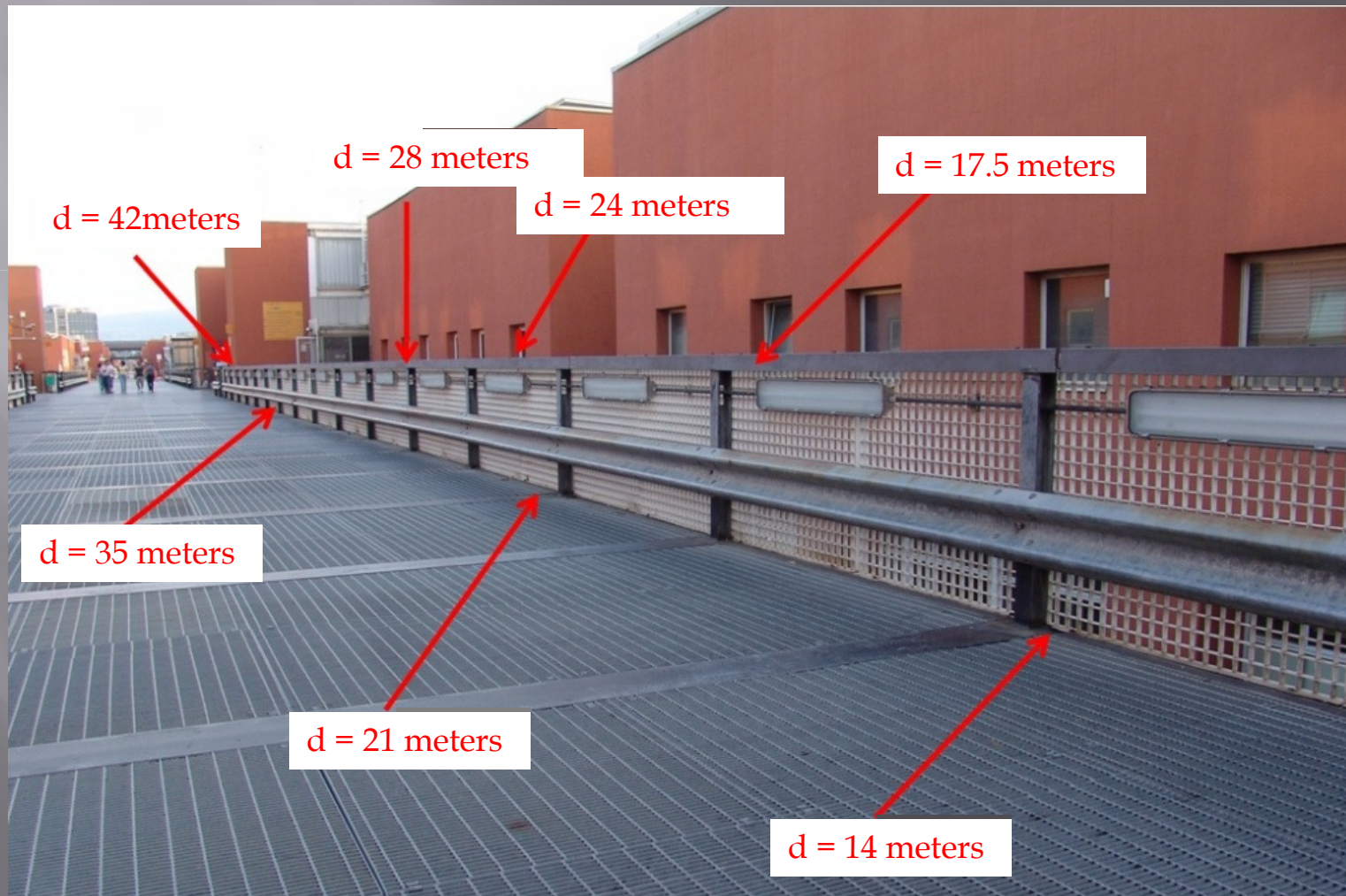
Examples of feasible measures



Wireless Channel Modeling

A practical case of study

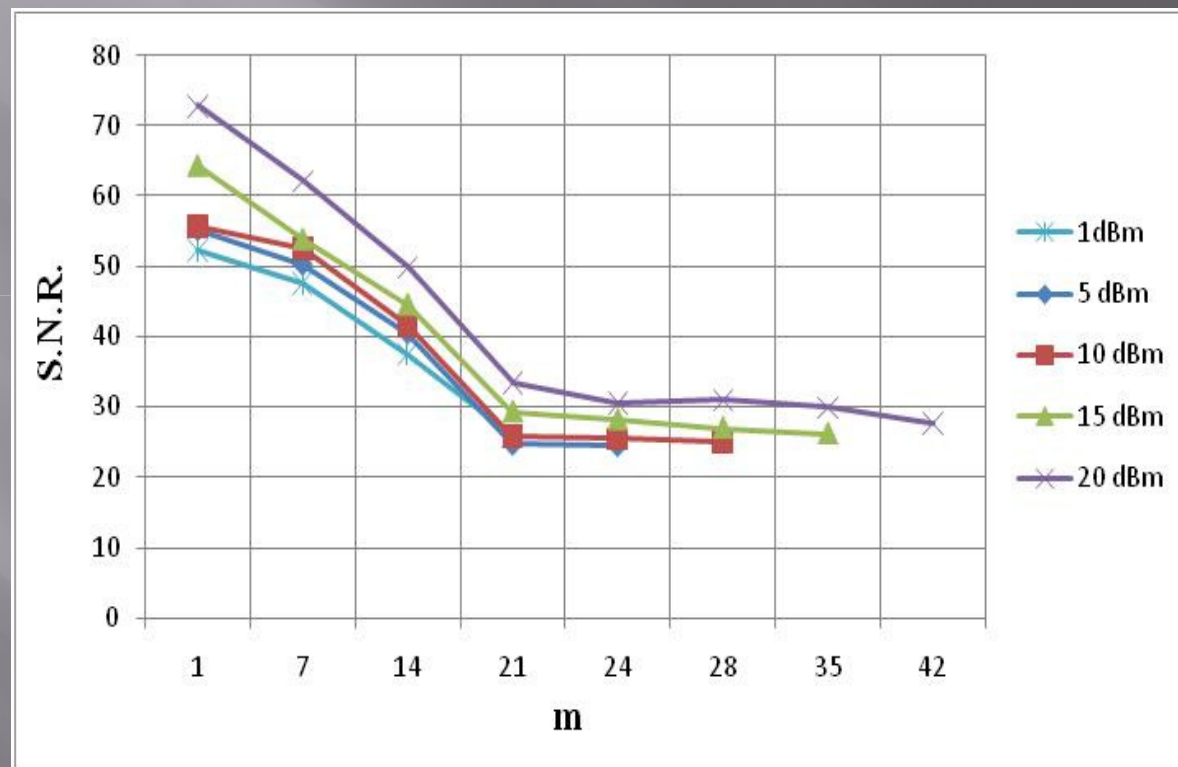
The considered scenario



Wireless Channel Modeling

A practical case of study

Numerical results



AVG SNR vs distance (fixed Tx power)

Wireless Channel Modeling

A practical case of study

Numerical results – PER vs distance and Tx power

Intel(R) PRO/Wireless 3945ABG Network Connection (Microsoft's Packet Scheduler) : Capturing - Wire

File Edit View Go Capture Analyze **Statistics** Telephony Tools Help

Filter: Expression... Clear Apply

No.	Time	Source	Destination	Protocol
4431	603.007207	192.168.0.3	89.135.164.126	TCP
4432	603.661082	89.135.164.126	192.168.0.3	Broadcast
4433	603.661124	192.168.0.3	89.135.164.126	TCP
4434	604.354166	89.135.164.126	192.168.0.3	TCP
4435	604.354212	192.168.0.3	89.135.164.126	TCP
4436	604.354404	89.135.164.126	192.168.0.3	TCP
4437	604.354420	192.168.0.3	89.135.164.126	TCP
4438	605.108467	75.182.23.55	192.168.0.3	TCP
4439	605.108557	192.168.0.3	75.182.23.55	TCP
4440	605.265785	75.182.23.55	192.168.0.3	TCP
4441	605.266101	192.168.0.3	75.182.23.55	TCP
4442	605.269679	75.182.23.55	192.168.0.3	Broadcast
4443	605.269711	192.168.0.3	75.182.23.55	TCP
4444	605.423725	75.182.23.55	192.168.0.3	TCP
4445	605.423779	192.168.0.3	75.182.23.55	TCP
4446	605.424013	75.182.23.55	192.168.0.3	TCP
4447	605.424038	192.168.0.3	75.182.23.55	TCP

Wireless Channel Modeling

A practical case of study (K=3)

Numerical results – Transition matrices

*$A_0 = 0$; $A_1 = A_0 + \text{Step}$; $A_2 = A_1 + \text{Step}$; ... $A_{n-1} = A_{n-2} + \text{Step}$; $A_n \propto$
 $\text{Step} = (\text{maxSNR} - \text{minSNR})/n$*

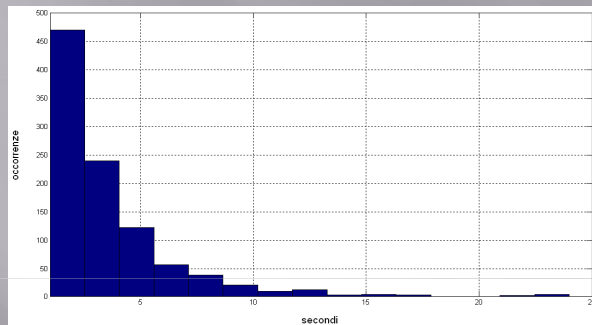
<u>1 meter 1dBm</u> 0.666667 0.292875 0.040476 0.000826 0.804959 0.194215 0.000758 0.029445 0.969797	<u>7 meters 1dBm</u> 0.854167 0.141667 0.004167 0.001075 0.795056 0.203870 0.000774 0.110488 0.888738	<u>14 meters 1dBm</u> 0.939227 0.058011 0.002762 0.031810 0.955080 0.013110 0.039370 0.259843 0.700787	<u>21 meters 1dBm</u> 0.870874 0.103883 0.025243 0.177258 0.792642 0.030100 0.042857 0.271429 0.685714
<u>1 meter 10dBm</u> 0.681159 0.252464 0.066377 0.002506 0.746032 0.251462 0.002125 0.033441 0.964434	<u>7 meters 10dBm</u> 0.656250 0.318750 0.025000 0.001182 0.822301 0.176517 0.001640 0.091207 0.907153	<u>14 meters 10dBm</u> 0.693122 0.306349 0.000529 0.007168 0.898276 0.094555 0.004527 0.157612 0.837861	<u>21 meters 10dBm</u> 0.693364 0.306636 0.000000 0.026967 0.972222 0.000811 0.083333 0.250000 0.666667
<u>28 meters 10dBm</u> 0.991290 0.006532 0.002177 0.315789 0.684211 0.000000 0.016667 0.250000 0.733333	<u>1 meter 20dBm</u> 0.785714 0.134921 0.079365 0.002867 0.823688 0.173446 0.001701 0.149729 0.848569	<u>7 meters 20dBm</u> 0.818141 0.181634 0.000225 0.161665 0.838135 0.000200 0.016667 0.316667 0.666667	<u>14 meters 20dBm</u> 0.656250 0.312500 0.031250 0.000759 0.820182 0.179059 0.001392 0.032855 0.965752
<u>21 meters 20dBm</u> 0.666667 0.283333 0.050000 0.003965 0.827686 0.168349 0.002135 0.071222 0.926643	<u>28 meters 20dBm</u> 0.753927 0.205934 0.040140 0.049765 0.884977 0.065258 0.053111 0.192716 0.754173	<u>35 meters 20dBm</u> 0.771394 0.217235 0.011370 0.066554 0.909261 0.024184 0.056566 0.242424 0.701010	<u>42 meters 20dBm</u> 0.704762 0.295238 0.000000 0.040222 0.940361 0.019417 0.071429 0.261905 0.666667

for different distances and Tx powers

Wireless Channel Modeling

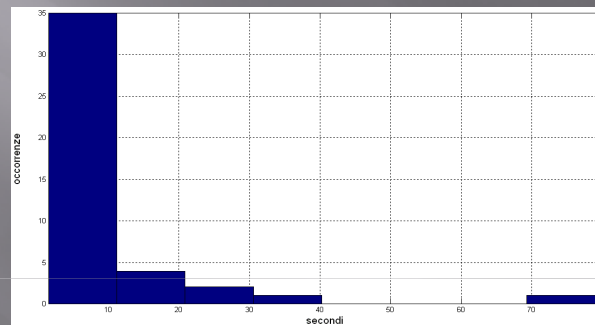
A practical case of study (K=3)

Numerical results – State Sojourn Time (SST) Distributions



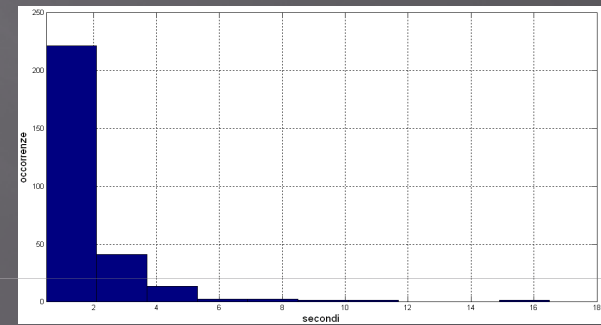
d =1 meter e Ptx = 20dBm

State 2



d =42 meter e Ptx = 20dBm

State 1



d =28 meter e Ptx = 20dBm

State 0

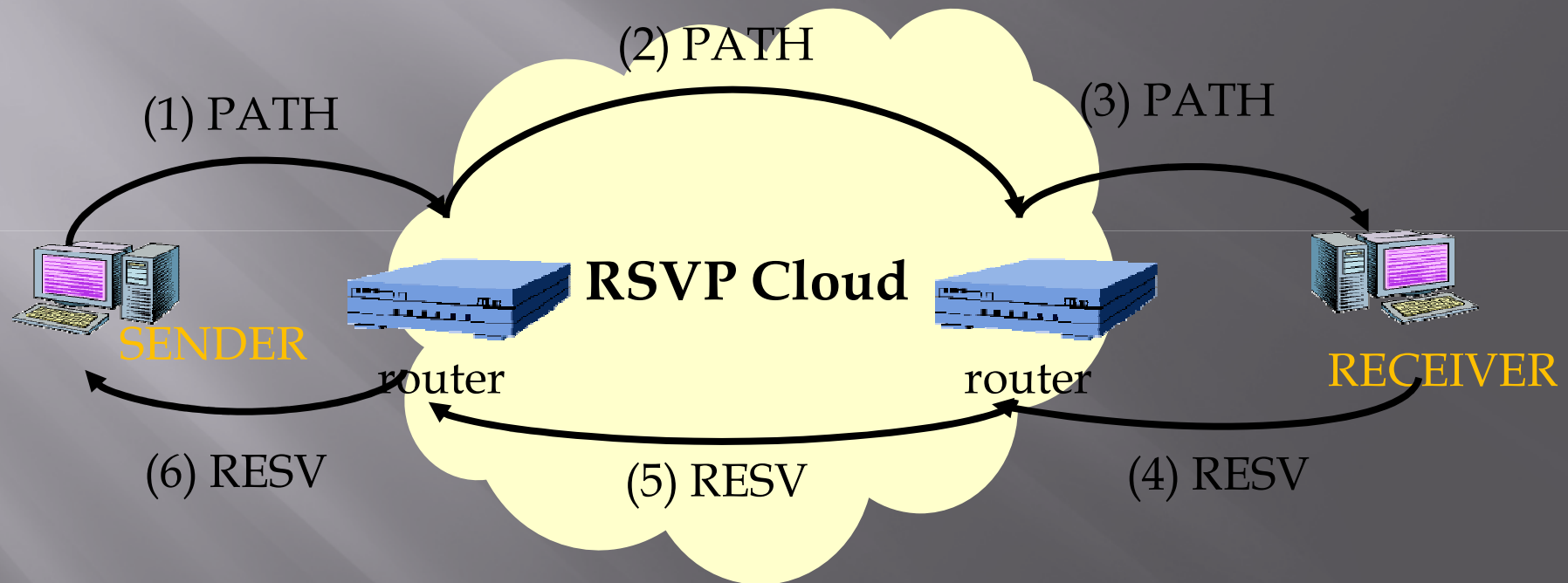
Exponential distribution can be considered for SSTs.

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Bandwidth Management

How can we use a similar approach in wireless networks with mobile hosts?



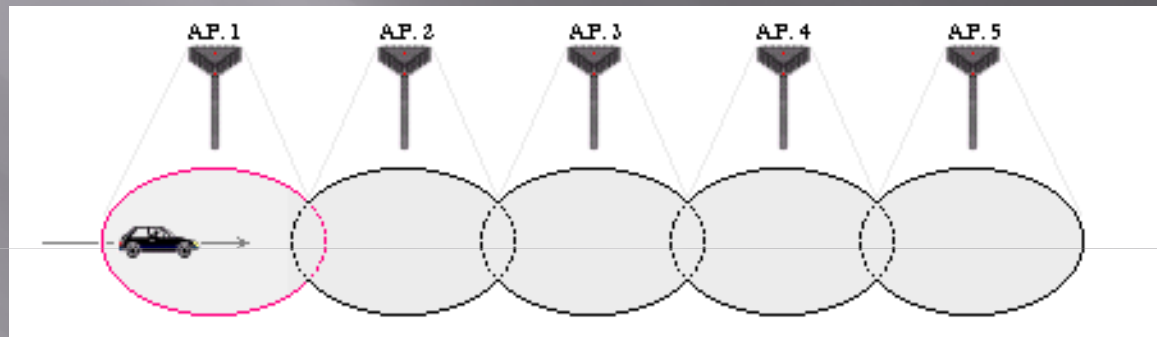
Mobile-RSVP (MRSVP) [Talukdar] is the extension of RSVP for mobility management.

[Talukdar]

A. K. Talukdar, B. R. Badrinath, A. Acharya, "MRSVP: a resource reservation protocol for an integrated services network with mobile hosts", *Wireless Netw.*

Bandwidth Management

- The power of MRSVP is based on the concepts of **active** and **passive** reservations;



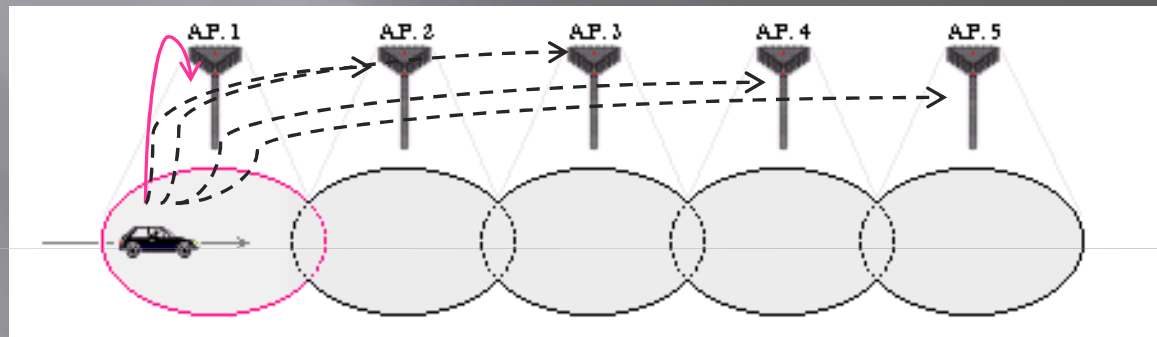
Without loss of generality, 1D case is considered

Active reservation: on the cell where the service request has originated;

Passive reservations: on the cells where the mobile host will arrive during its Call Holding Time (CHT);

Bandwidth Management

An **Active-RESV** message is sent to the current coverage cell;



Without loss of generality, 1D case is considered

Passive-RESV messages are sent to the remote cells;

Question: how many cells will a mobile host visit?

Bandwidth Management

Passive Reservation Issues

1D scenario:

How many cells will the mobile host visit?

2D scenario:

How many cells will the mobile host visit?

What cells will the mobile host visit?

Open Issues:

What kind of mobility analysis needs
to be made?

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.

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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.

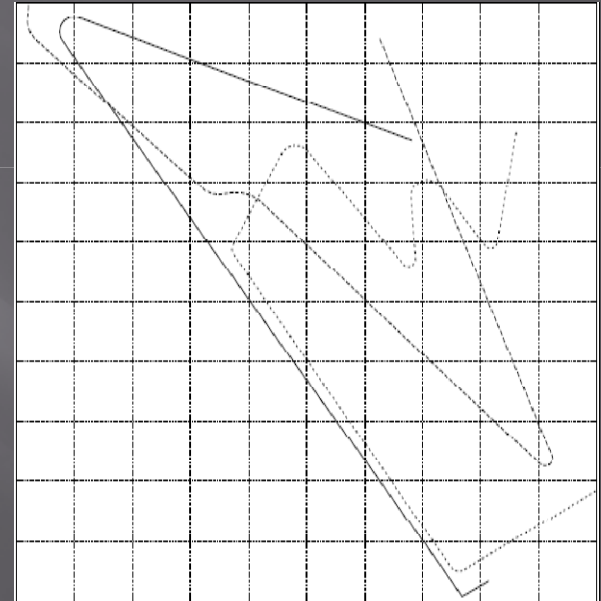
Pro: real user patterns;

Con: need of accessing TLC companies DBs.

Mobility Generation

SYNTHETIC MOBILITY – “SOME” EXAMPLES

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



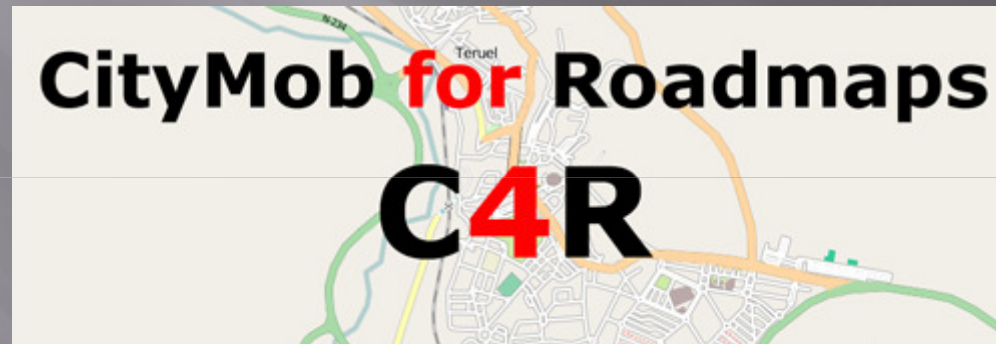
Pro: analytical expressions available;

Con: real environments cannot be considered.

Mobility Generation

GEOGRAPHICAL PATTERNS – EXAMPLE

City 4 Roadmaps [Martinez]



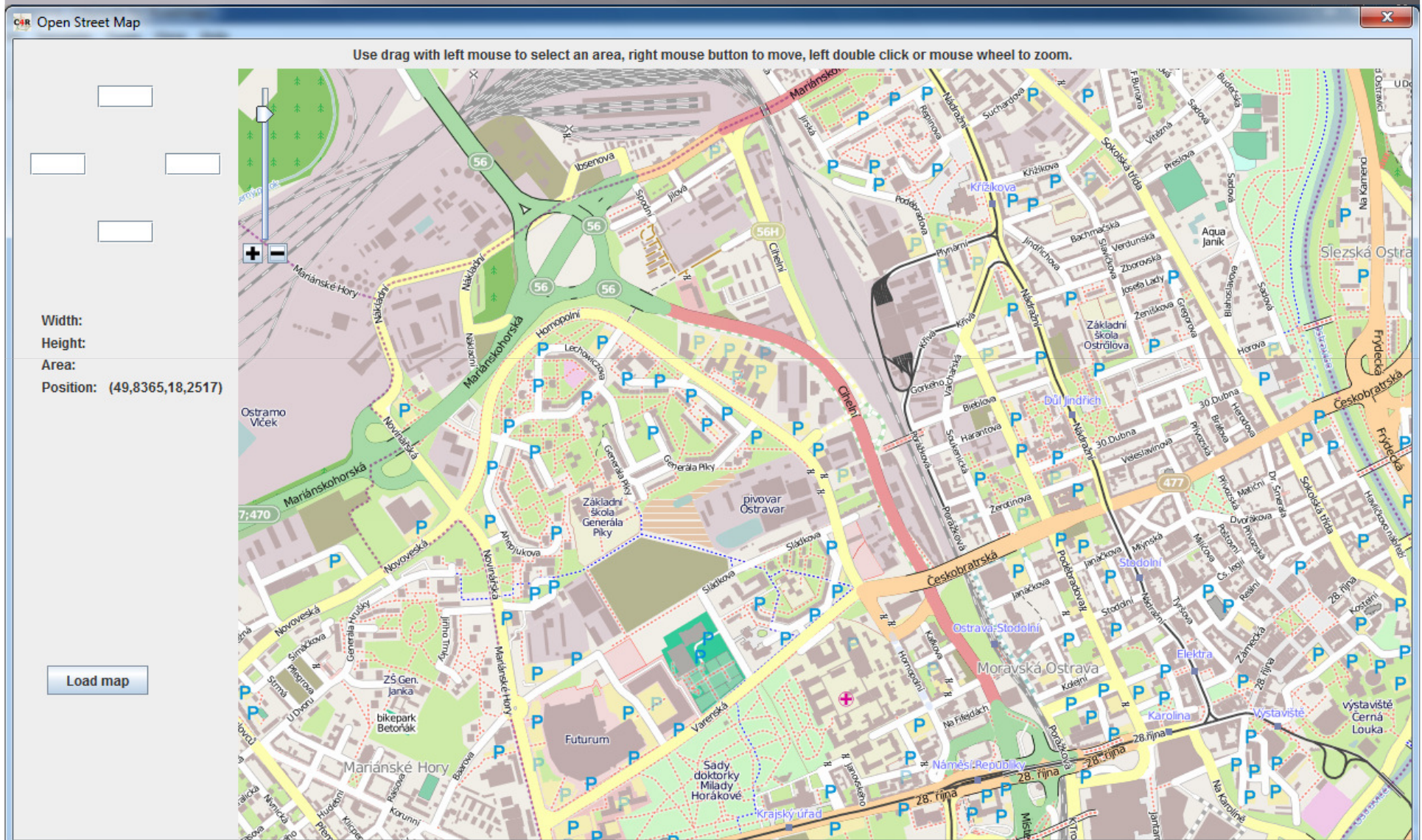
It is a mobility generator software based on real roads (www.openstreetmap.org), which can be chosen for the considered coverage area.

[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

RND

Wizard progress
Step 4 of 5

Please, select a mobility model

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

Acceleration (m/s²)

Deceleration (m/s²)

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](#)

< Back Next > Cancel

Position (1.633,33,-264,22)

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 "$node_(0) setdest 20
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ns_ at 23.0 "$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
"$node_(0) setdest 1711.9689382602492 462.8689889286944 9.5199999999999843"$ns_ at 47.0 "$node_(0) setdest 1704.8219968849603 460.4978860253633 7.5300000000000
585 10.6600000000000029"$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_
500000000000135"$ns_ at 81.0 "$node_(0) setdest 1307.7203504884594 318.6626662232337 13.809999999999915"$ns_ at 82.0 "$node_(0) setdest 1294.5179664531222 31
dest 1142.7416929833369 278.52782213957624 24.039769935939255"$ns_ at 93.0 "$node_(0) setdest 1131.6495335068382 270.58971164979823 13.640000000000008"$ns_ at
42 13.450000000000005"$ns_ at 104.0 "$node_(0) setdest 1005.9500428208664 172.8008608331129 23.200025551125457"$ns_ at 105.0 "$node_(0) setdest 995.395609677
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"$ns_ at 23.0 "$node_(1) setdest 2295.4450095081106 186.5508916712744 5.637324224248126"$ns_ at 24.0 "$node_(1) setdest 2288.9046480278694 181.857686827271 8
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at 127.0 "$node_(1) setdest 1534.5081353755427 398.31481731893456 13.74431817740803"$ns_ at 128.0 "$node_(1) setdest 1522.0227642093216 393.313248863154 13.4
00158056533 342.2535175699035 13.879864140678968"$ns_ at 139.0 "$node_(1) setdest 1382.7762270017322 337.3317361840561 13.539999999999994"$ns_ at 140.0 "$nod
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999999974"$ns_ at 196.0 "$node_(1) setdest 782.9520595988308 212.64731110455918 22.93644652828363"$ns_ at 197.0 "$node_(1) setdest 771.7147506799487 233.0778
698.012799745916 289.59744410212386 8.3100000000000077"$ns_ at 208.0 "$node_(1) setdest 691.1883235592163 285.86181500153486 7.779999999999922"$ns_ at 209.0 "
$ns_ at 219.0 "$node_(1) setdest 613.4787675978107 243.32461936899256 8.169999999999982"$ns_ at 220.0 "$node_(1) setdest 606.2858749588726 239.3873239159296
6 200.65778108128848 8.320000000000007"$ns_ at 231.0 "$node_(1) setdest 528.6114062786326 196.86933460267056 7.889999999999998"$ns_ at 232.0 "$node_(1) setdest
#Path $node_(2) = random_undefined_2_0$ns_ at 0.0 "$node_(2) setdest 100.97310813770575 587.0945426243177 1.3600000000000063"$ns_ at 1.0 "$node_(2) setdest 1
est 120.6810642510742 512.7358679654897 8.090022332257925"$ns_ at 12.0 "$node_(2) setdest 125.03026701302244 506.297130873834 7.770000000000017"$ns_ at 13.0
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```


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?

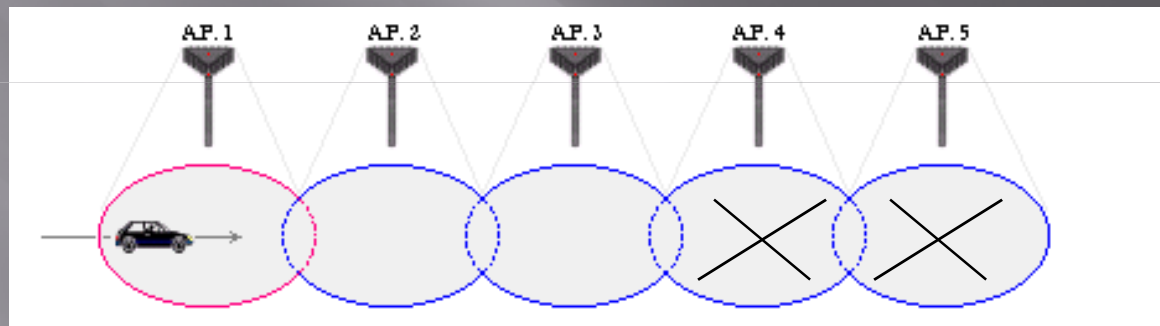
How can the number of h.o. be evaluated?

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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Cell 4

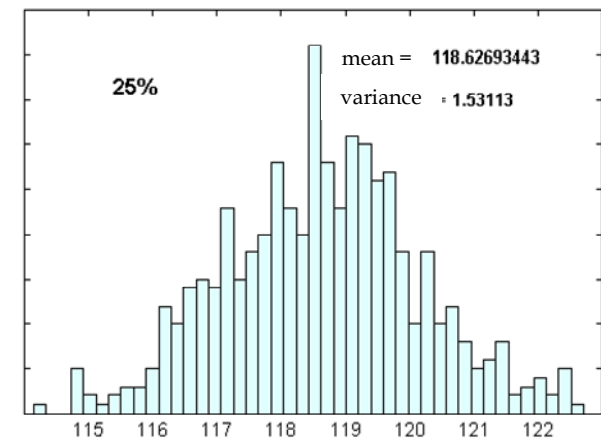
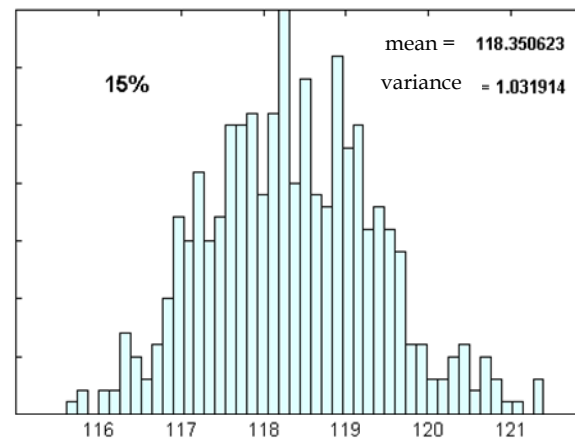
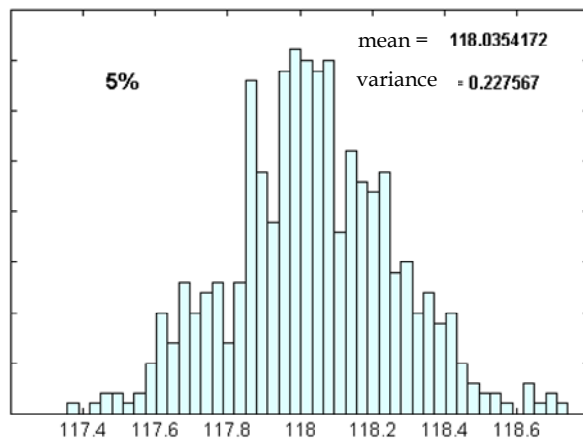
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Cell 5

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:

$$C_p = \left\lceil \frac{T_{CHT}}{T_{CST}} \right\rceil$$

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