

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

**Ing. Peppino Fazio**

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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



# Executive Summary

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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.

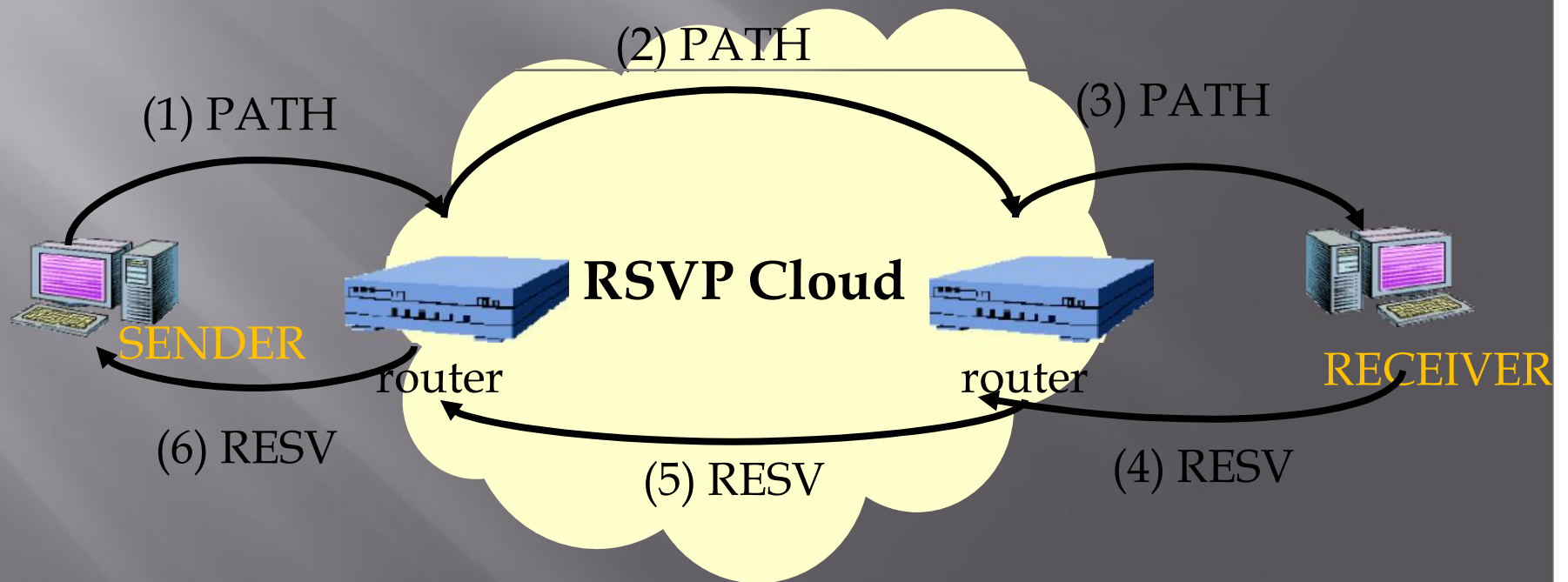
Source: CQOS Inc.

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





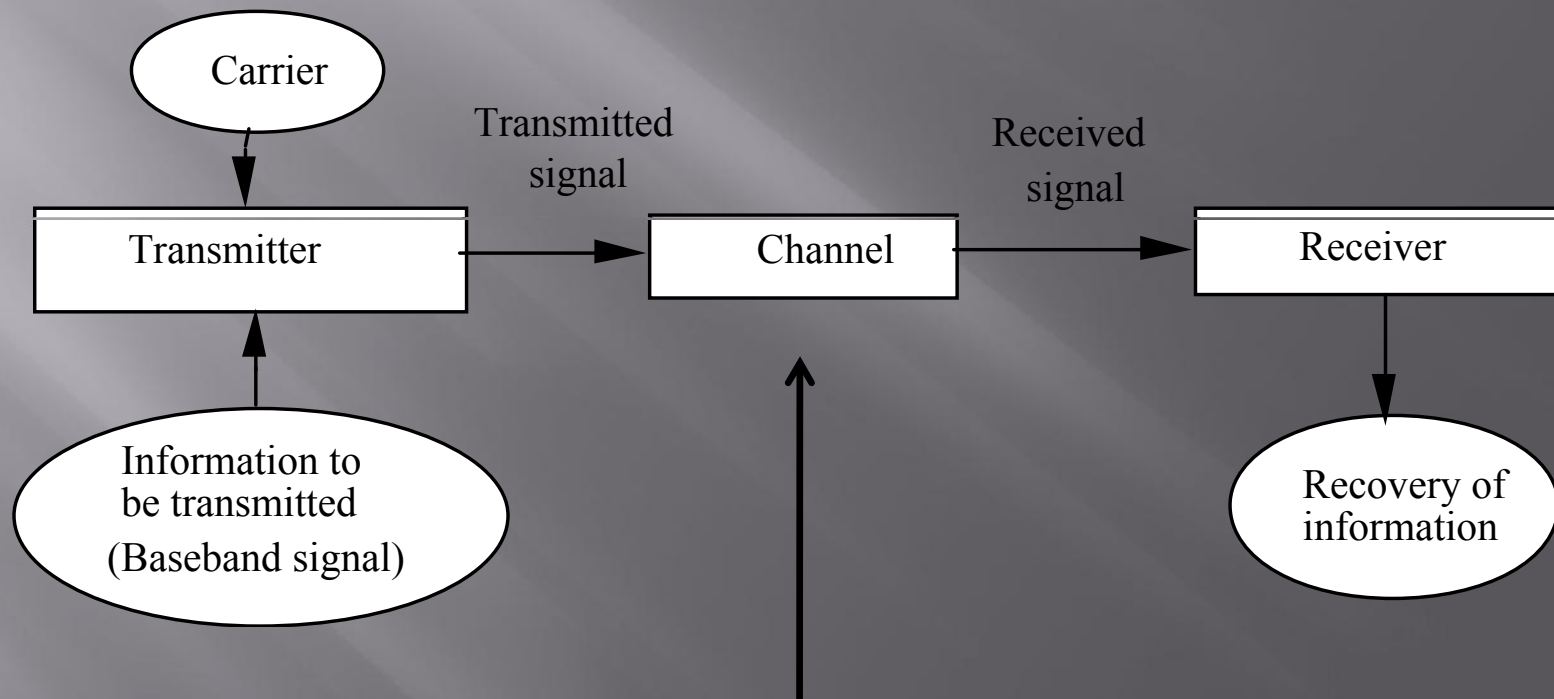
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# Wireless Communications and Issues

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

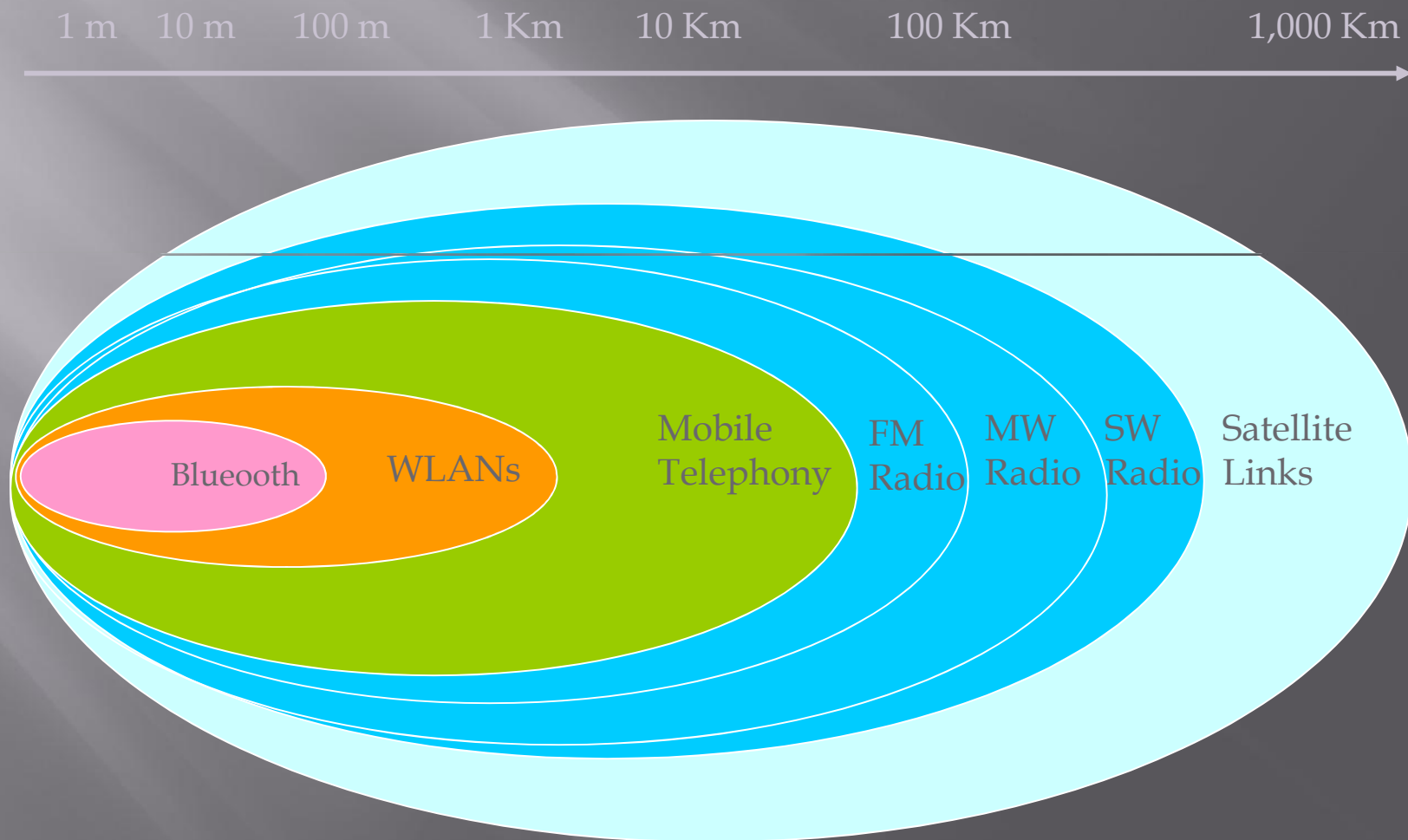
UltraWideBand (UWB) Radios

Zigbee Radios



# Wireless Communications and Issues

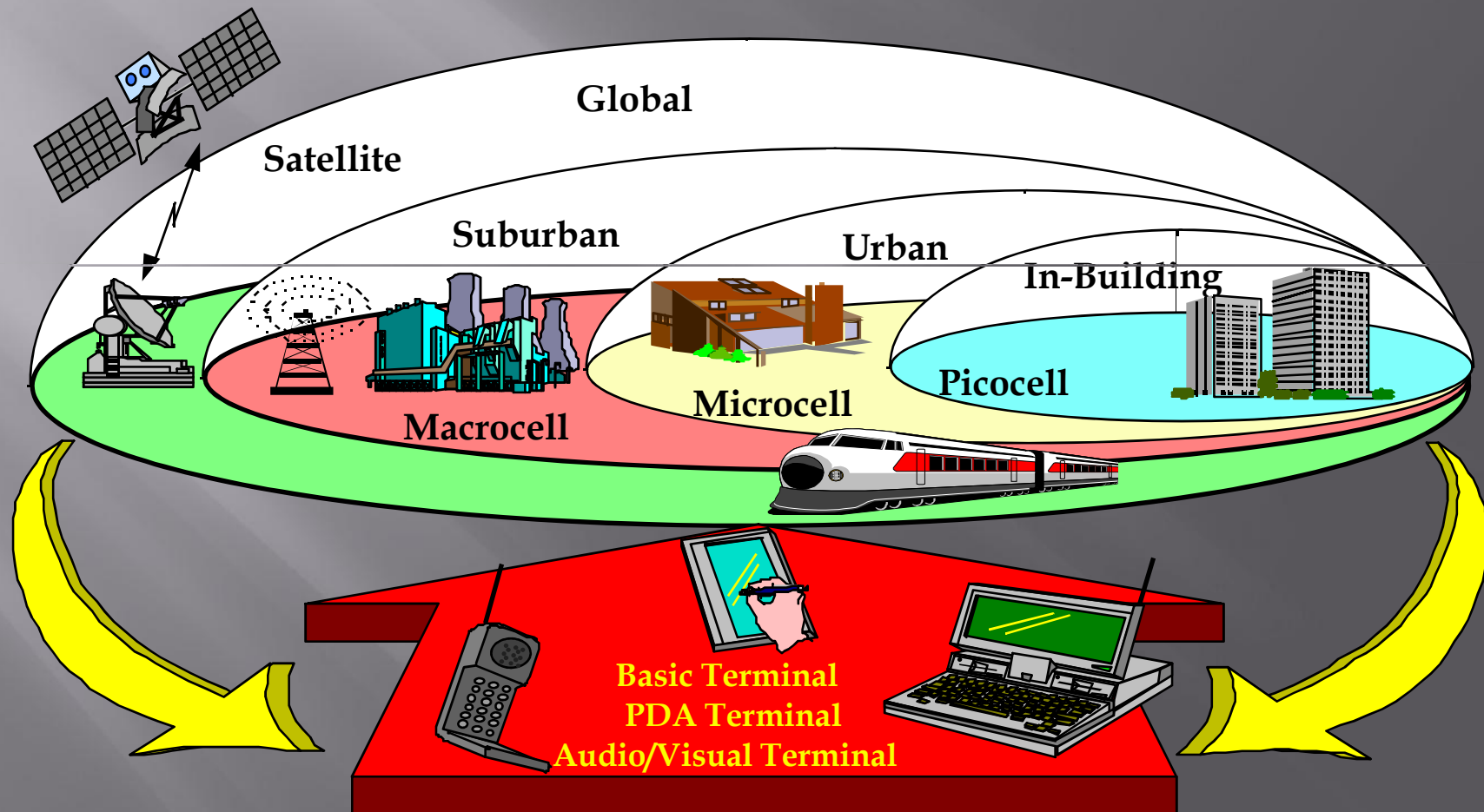
## RANGE COMPARISON





# 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.



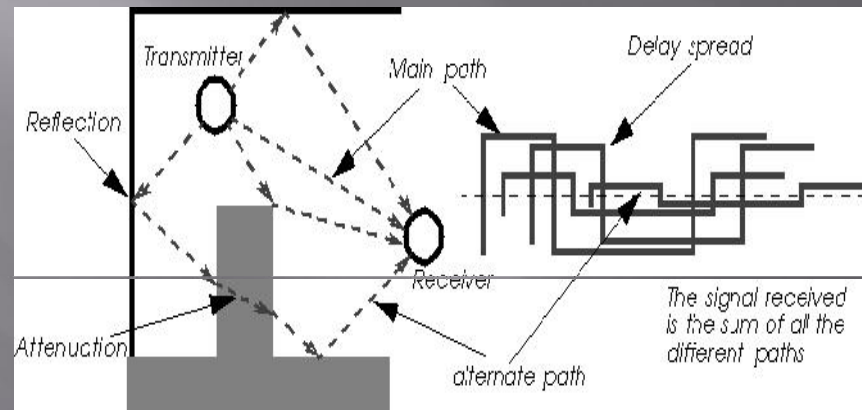
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# Wireless Channel Modeling

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;

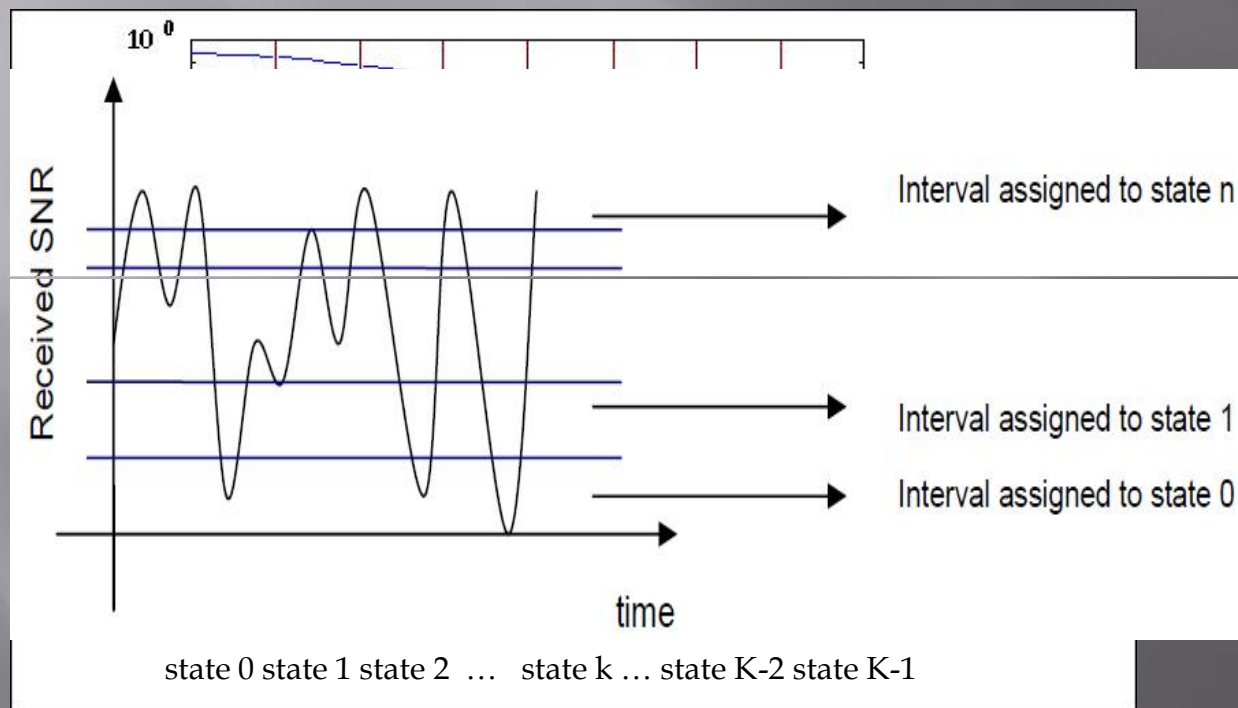
$$\text{TX} \longrightarrow s(t) = \text{Re} \left[ s_l(t) e^{j2\pi f_c t} \right] \xrightarrow{\text{WIRELESS LINK}} x(t) = \sum_n \alpha_n(t) s[t - \tau_n(t)], \text{RX}$$

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:



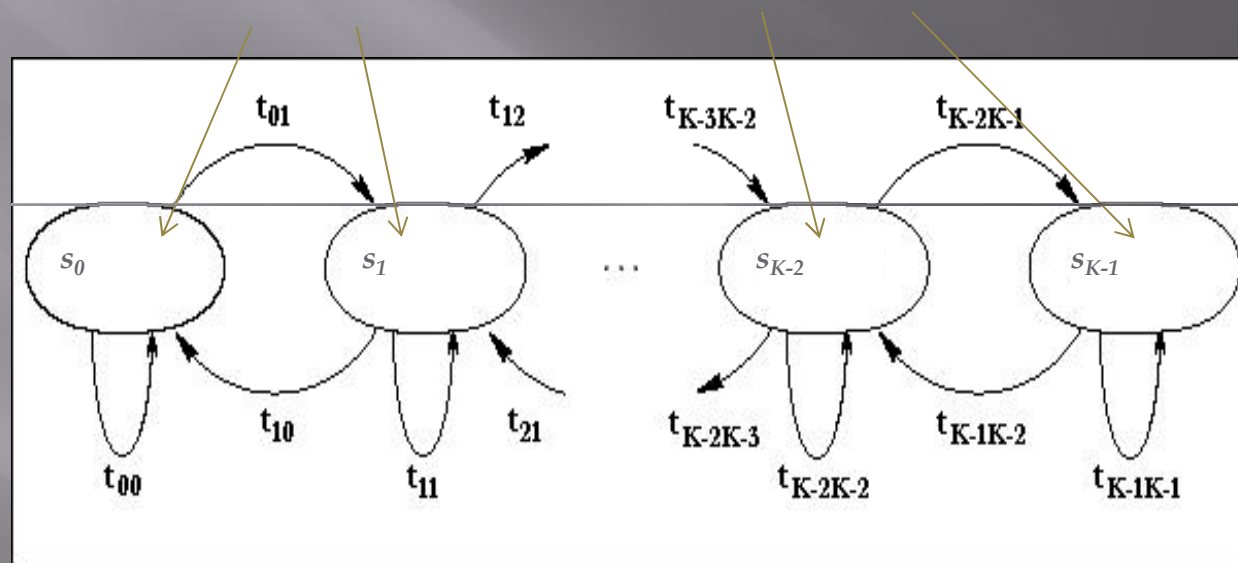
PARTITIONING

[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.



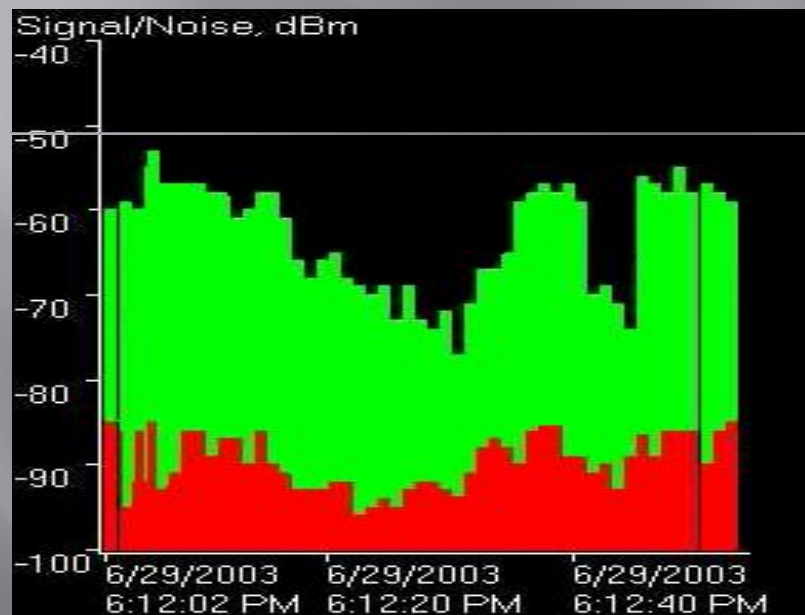
# Wireless Channel Modeling

## *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	Size
1	0.00000	192.168.0.1	192.168.0.2	IF	Fragmented IP protocol (proto TCP, offset 0)
2	0.00000	192.168.0.1	192.168.0.2	IF	Fragmented IP protocol (proto TCP, offset 1600)
3	0.00000	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
4	0.00000	192.168.0.2	192.168.0.1	IF	Fragmented IP protocol (proto TCP, offset 0)
5	0.00000	192.168.0.2	192.168.0.1	IF	Fragmented IP protocol (proto TCP, offset 1600)
6	0.00000	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
7	0.00000	192.168.0.1	192.168.0.2	IF	Fragmented IP protocol (proto TCP, offset 0)
8	0.00000	192.168.0.1	192.168.0.2	IF	Fragmented IP protocol (proto TCP, offset 1600)
9	0.00000	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
10	0.00000	192.168.0.2	192.168.0.1	IF	Fragmented IP protocol (proto TCP, offset 0)
11	0.00000	192.168.0.2	192.168.0.1	IF	Fragmented IP protocol (proto TCP, offset 1600)
12	0.00000	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
13	0.00000	192.168.0.1	192.168.0.2	IF	Fragmented IP protocol (proto TCP, offset 0)
14	0.00000	192.168.0.1	192.168.0.2	IF	Fragmented IP protocol (proto TCP, offset 1600)
15	0.00000	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
16	0.00000	192.168.0.2	192.168.0.1	IF	Fragmented IP protocol (proto TCP, offset 0)
17	0.00000	192.168.0.2	192.168.0.1	IF	Fragmented IP protocol (proto TCP, offset 1600)
18	0.00000	192.168.0.1	192.168.0.2	ICMP	Echo (ping) request
19	0.00000	192.168.0.1	192.168.0.2	IF	Fragmented IP protocol (proto TCP, offset 0)
20	0.00000	192.168.0.1	192.168.0.2	IF	Fragmented IP protocol (proto TCP, offset 1600)

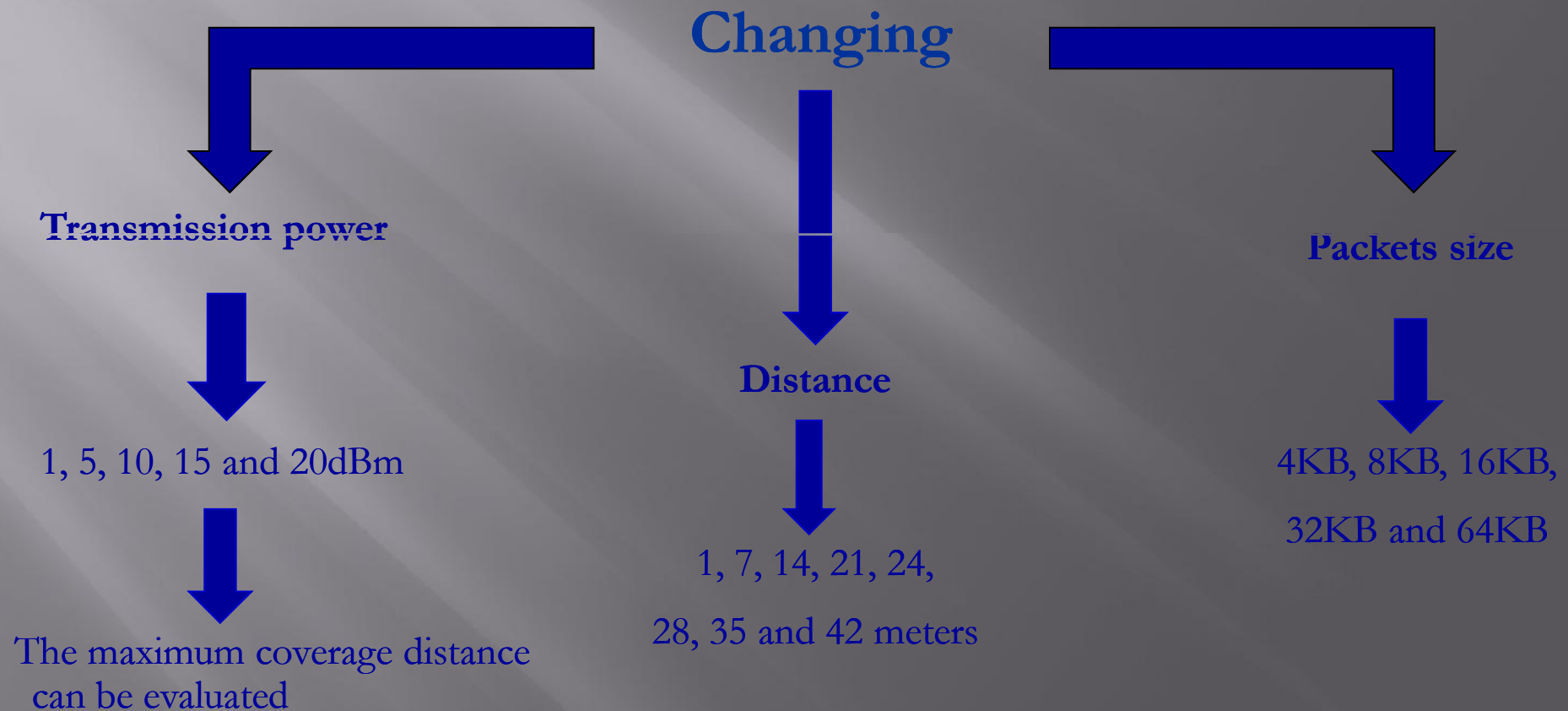
Protocol analyzer



# Wireless Channel Modeling

## *A practical case of study*

### Examples of feasible measures

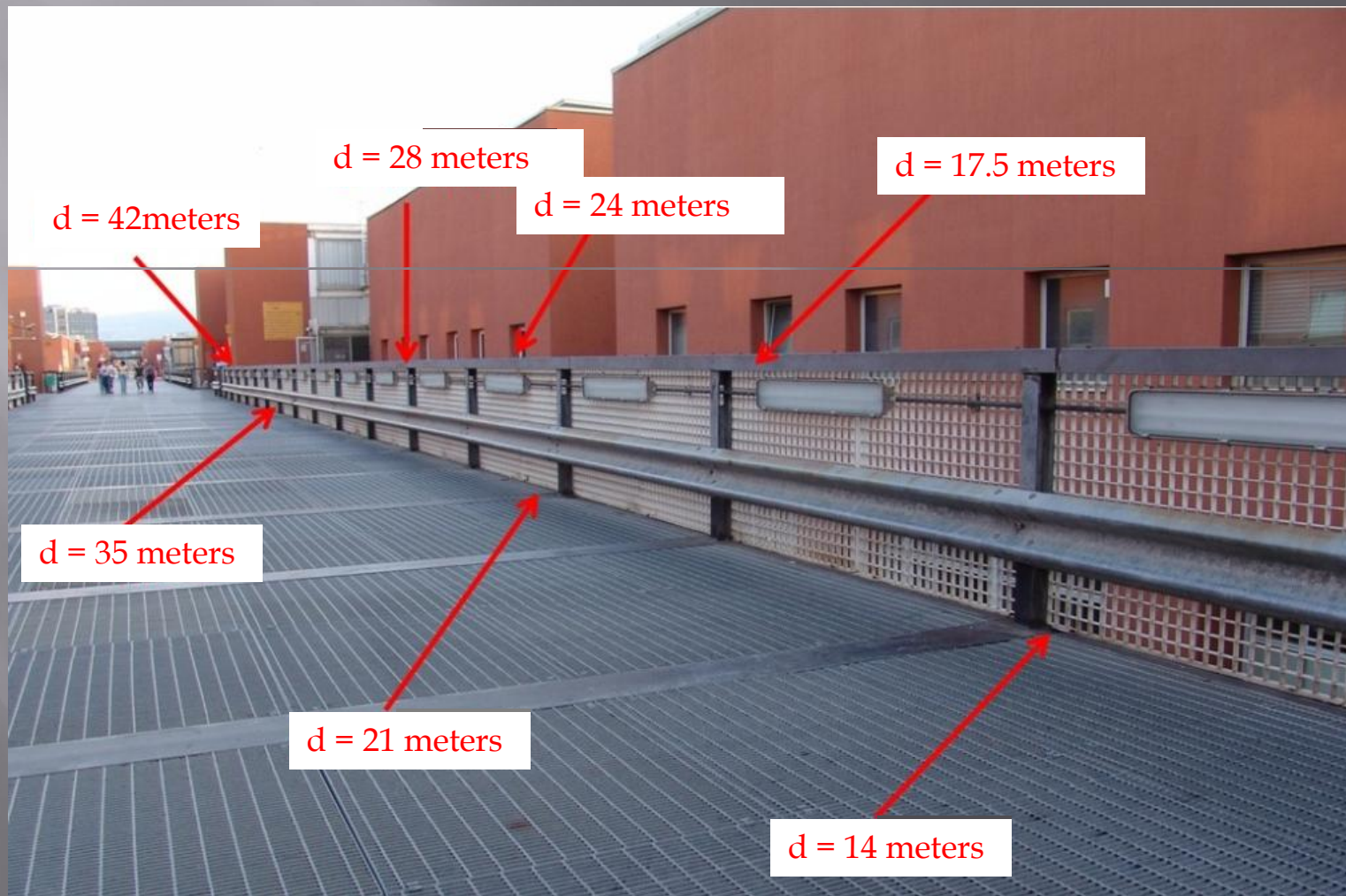




# Wireless Channel Modeling

## *A practical case of study*

*The considered scenario*

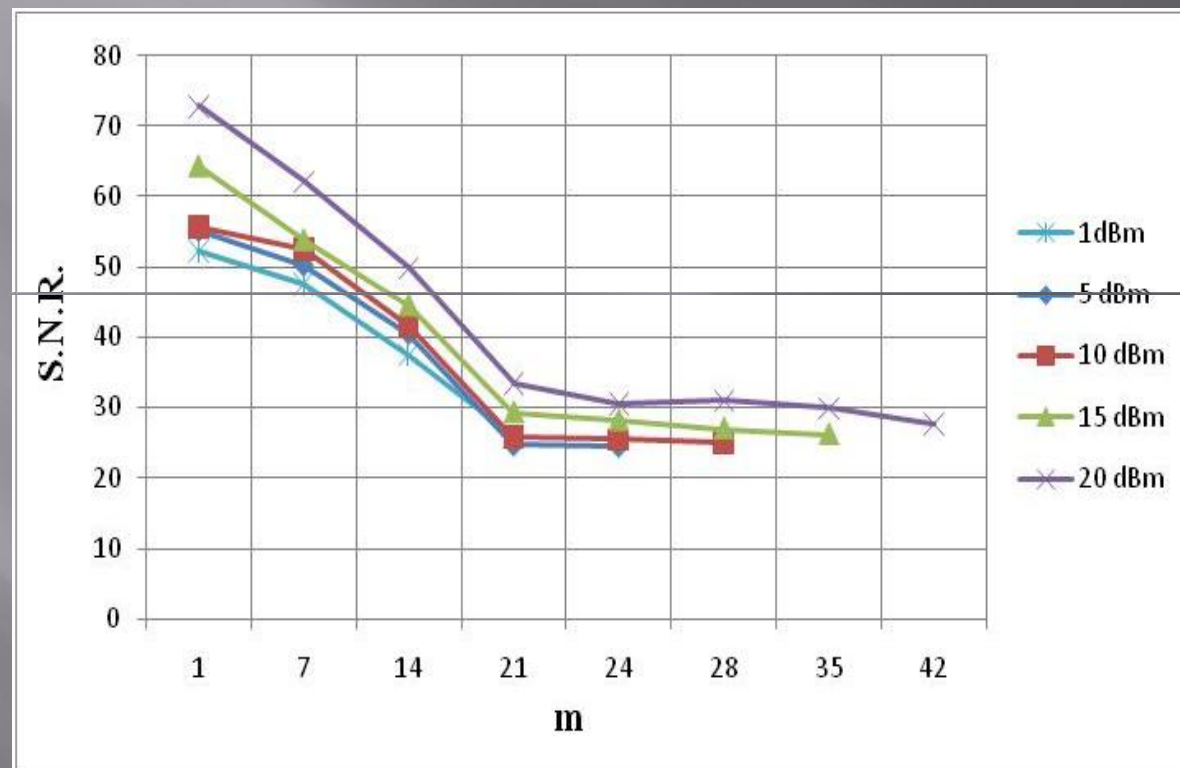




# Wireless Channel Modeling

## *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	Pro
4431	603.007207	192.168.0.3	89.135.164.126	TC
4432	603.661082	89.135.164.126	192.168.0.3	Bi
4433	603.661124	192.168.0.3	89.135.164.126	TC
4434	604.354166	89.135.164.126	192.168.0.3	TC
4435	604.354212	192.168.0.3	89.135.164.126	TC
4436	604.354404	89.135.164.126	192.168.0.3	TC
4437	604.354420	192.168.0.3	89.135.164.126	TC
4438	605.108467	75.182.23.55	192.168.0.3	TC
4439	605.108557	192.168.0.3	75.182.23.55	TC
4440	605.265785	75.182.23.55	192.168.0.3	TC
4441	605.266101	192.168.0.3	75.182.23.55	TC
4442	605.269679	75.182.23.55	192.168.0.3	Bi
4443	605.269711	192.168.0.3	75.182.23.55	TC
4444	605.423725	75.182.23.55	192.168.0.3	TC
4445	605.423779	192.168.0.3	75.182.23.55	TC
4446	605.424013	75.182.23.55	192.168.0.3	TC
4447	605.424038	192.168.0.3	75.182.23.55	TC



# Wireless Channel Modeling

## *A practical case of study (K=3)*

*Numerical results – Transition matrices*

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

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

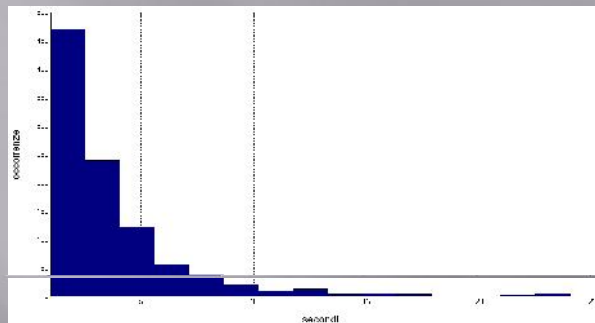
*for different distances and Tx powers*



# Wireless Channel Modeling

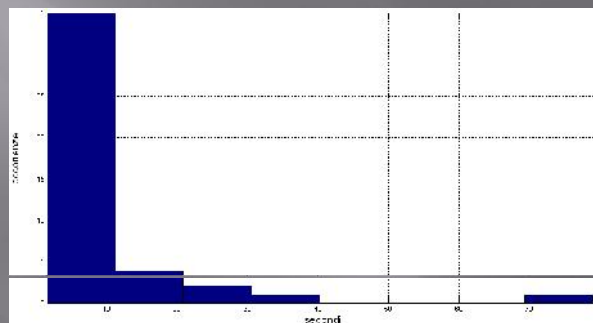
## *A practical case of study (K=3)*

*Numerical results – State Sojourn Time (SST) Distributions*



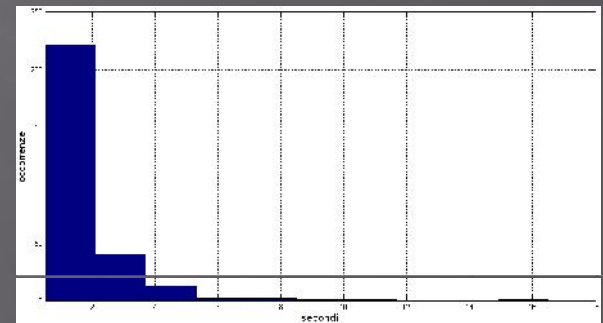
d =1 meter e Ptx = 20dBm

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.*