# Adaptive Energy Efficient Communications for Hybrid Aerial-Terrestrial Systems

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# Outline

1 Introduction & Scenarios

2 Communication Network Models

3 Simulation Results

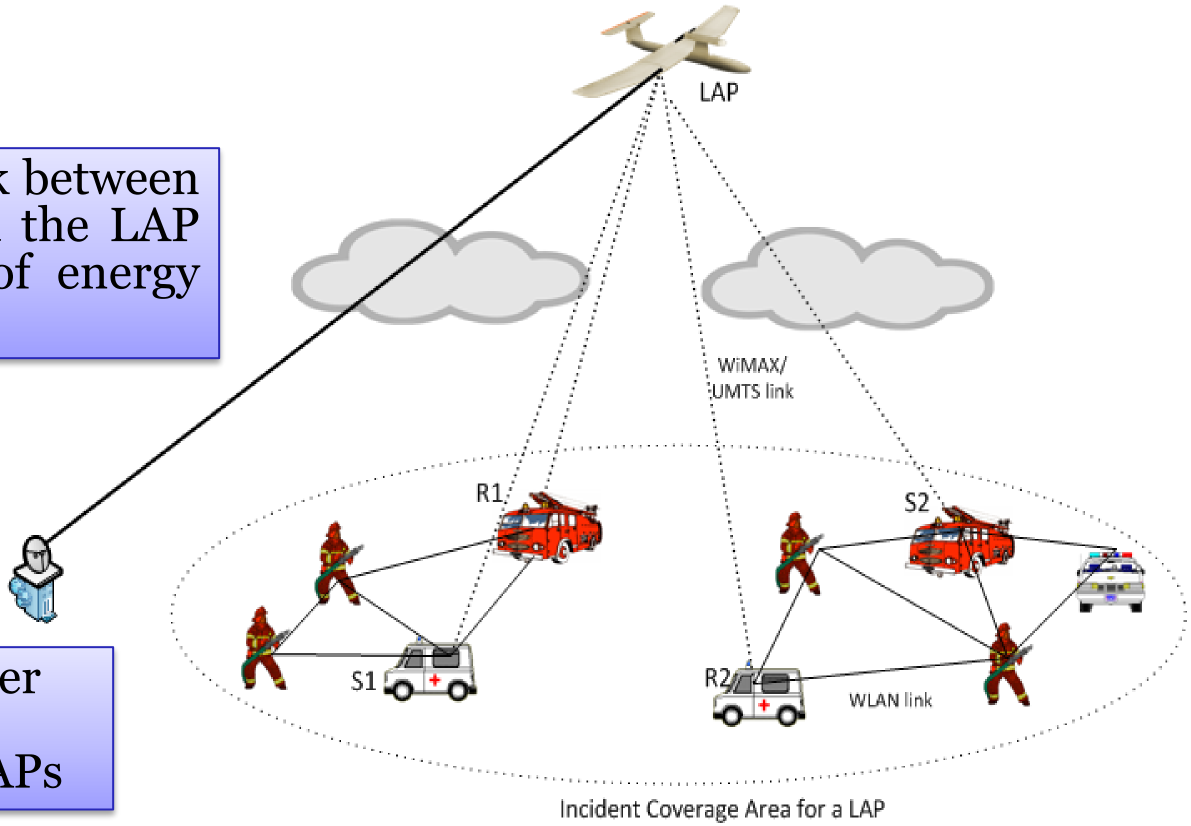
4 Conclusions and Future work

# Outline

# Aerial Telecommunication System Architecture for Emergency response

Large-scale natural disasters cause damage on networking infrastructure affecting seriously the communication services.

# Scenario for LAP-Terrestrial (LAP-T) communication with cooperative relay links

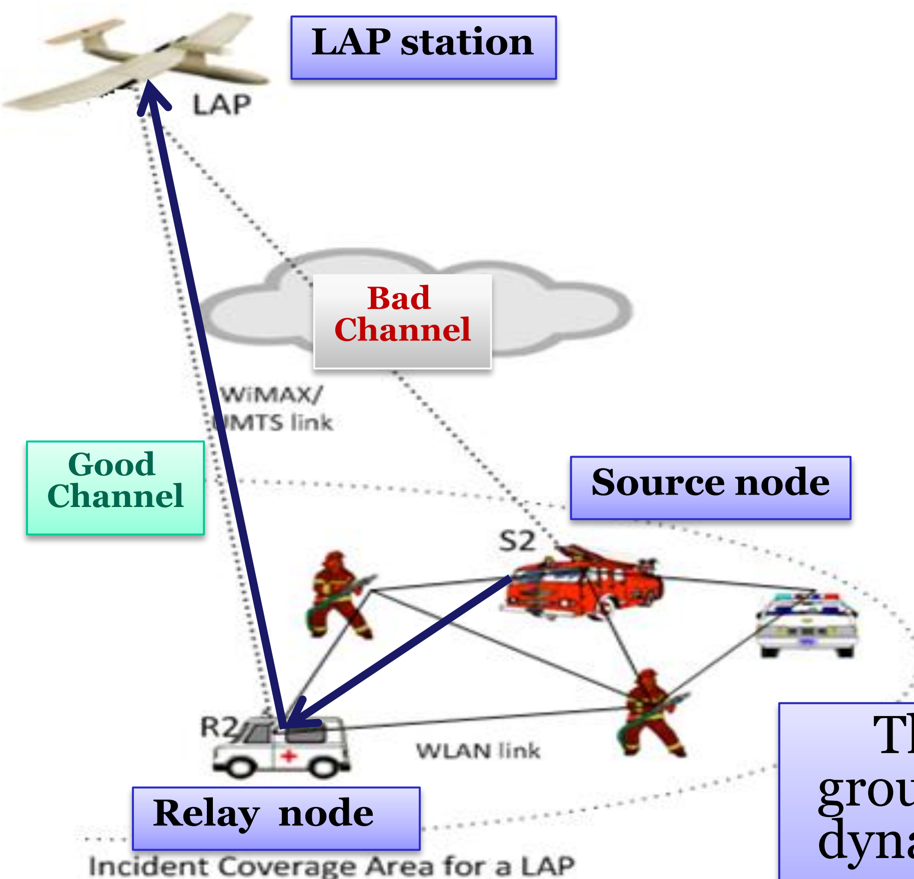



The communication link between the ground devices and the LAP is a significant cause of energy consumption

Devices need to spend higher power in the uplink communication with the LAPs

The ground terminals operated using battery

# Scenario for LAP-Terrestrial (LAP-T) communication with cooperative relay links



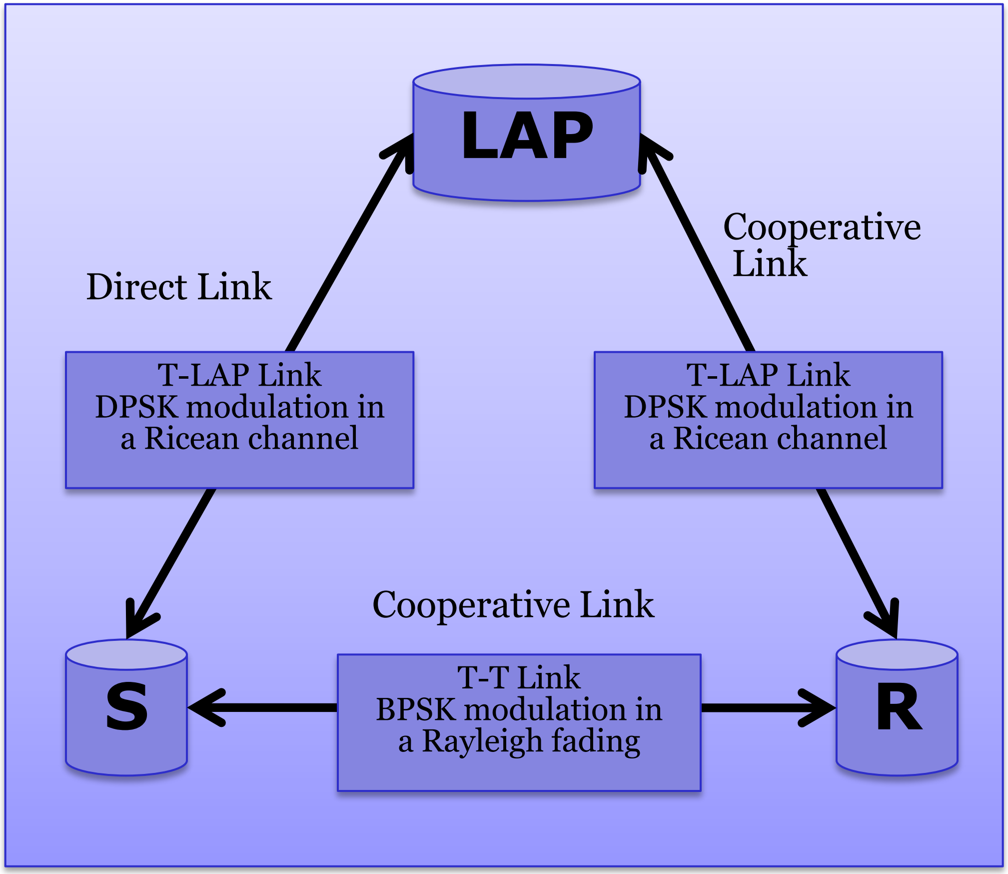

LAP-T channels can vary due to various conditions

Cooperative relaying strategies can be used to improve the energy efficiency of the network

The overall lifetime of the mobile ground terminals can be optimized by dynamically adapting between **direct and cooperative relay links**

# Outline

# Communication Nertwork Model

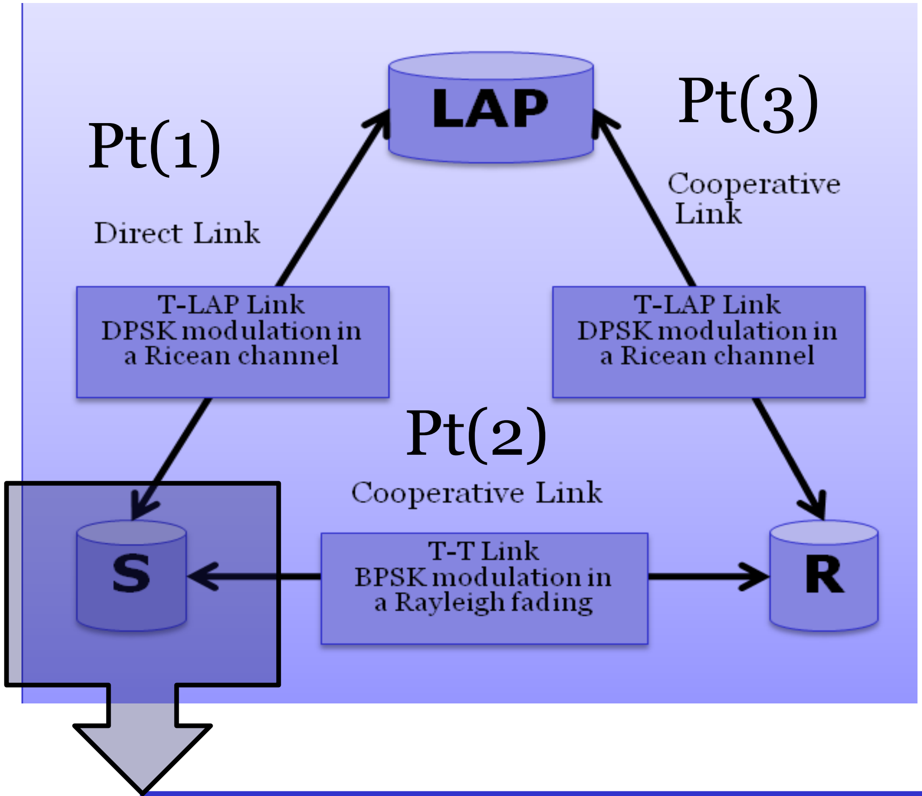



**Assumption**
**(Cognitive context aware)**

Terrestrial nodes known:

- Tx-Rx separations
- Channel power gains
- Pathloss exponent
- Transmitted signal power
- Tx and Rx antenna gains
- Data rate for link i

# Optimum Power Allocation for Energy Efficient Cooperative Communication




- Pt(1) is the source transmission power for the aerial-interface.
- Pt(2) is the source transmission power for the Terrestrial-interface.
- Pt(3) is the relay transmission power for the aerial interface.

The QoS beteween direct and cooperative link is the same

The optimum source transmit power Pt(2) is computed by using optimum relay transmit power Pt(3)

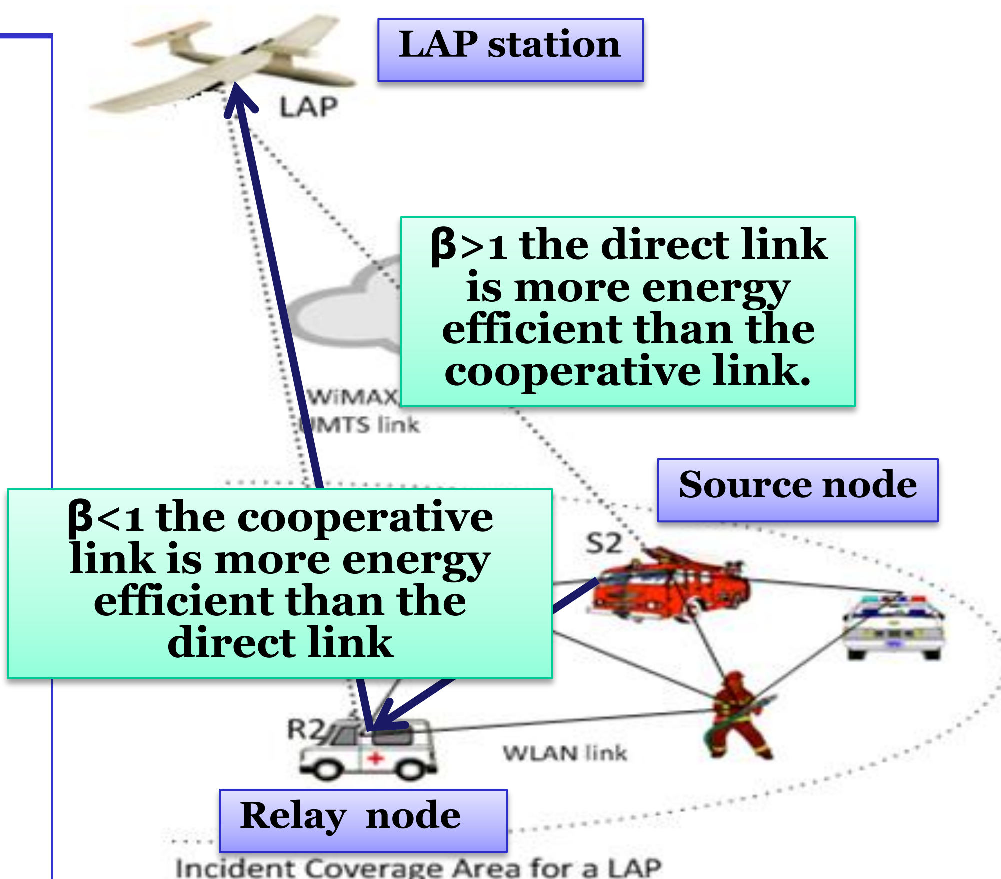
- Source has two interfaces aerial and terrestrial
- Source node decides to choose the relay link over the direct link for power efficiency.

# Energy efficiency factor (β)

$$\beta \triangleq \frac{[P_t(2) + P_t(3)]}{P_t(1)}$$

β is a metric to compare the energy efficiency between the direct and relay links

- Pt(1) is the source transmission power for the aerial-interface
- Pt(2) is the source transmission power for the Terrestrial-interface
- Pt(3) is the relay Tx for the aerial interface.



# REAL-TIME ADAPTIVE HYBRID TERRESTRIAL-LAP TRANSMISSION FOR ENERGY EFFICIENCY

**Algorithm 1** Adaptive transmission power schem

```
Procedure at the source
if Queue is not empty then
   BER = calculateBER[Pt(1),SNR1]
   Pt(3) = calculatePt[BER,SNR2,SNR3]
   Pt(2) = calculatePt[Pt(3),SNR2,SNR3]
   if Pt(1) ≤ Pt(2) + Pt(3) then
      Tx = Pt(1)
      p = Queue.next()
      sendDirectLink(p)
   else
      Tx = Pt(2)
      p = Queue.next()
      sendCooperativeLink(p)
   end if
end if
Procedure at the relay
if receive(p)=relay packet then
   Tx = Pt(3)
   sendDirectLink(p)
end if
```

**SOURCE**

1. S calculates the BER for the uplink source-LAP using **Pt(1)** and the channel conditions of the direct link.
2. S calculates the optimum power allocation **Pt(3)** for the relay using the BER of the uplink source-LAP and the channel conditions of the cooperative link.
3. S calculates **Pt(2)** for the source using Pt(3) and the channel conditions of the cooperative link.
4. S decides to choose the cooperative link or the direct link for power efficiency **Pt(1) < Pt(2)+Pt(3) (β)**

**RELAY**

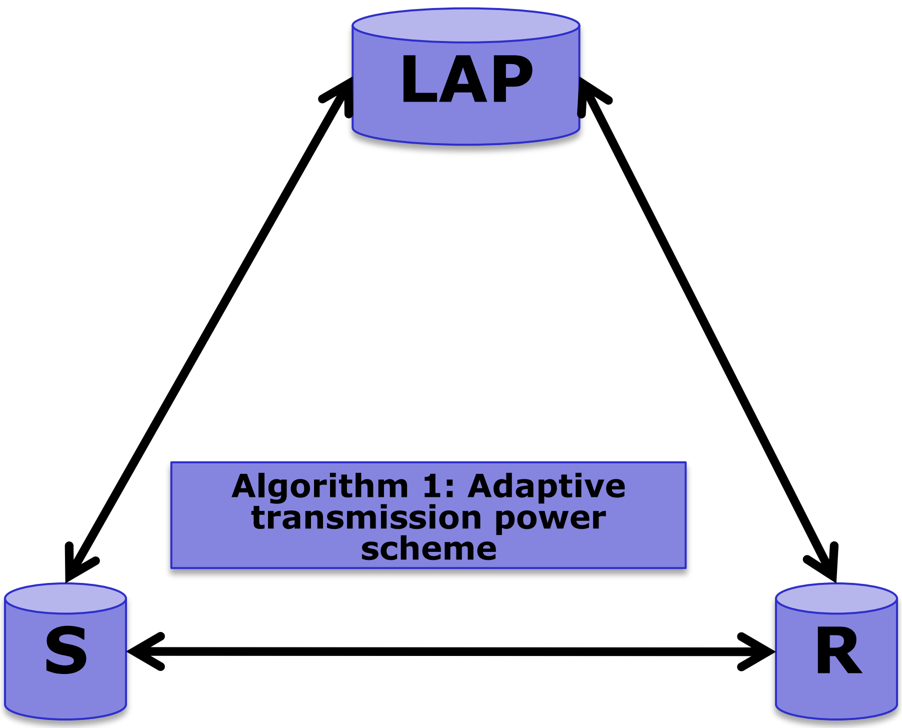
1. R sends the packet to the LAP through the direct link with **Pt(3)**

# Outline

# Simulation Scenario

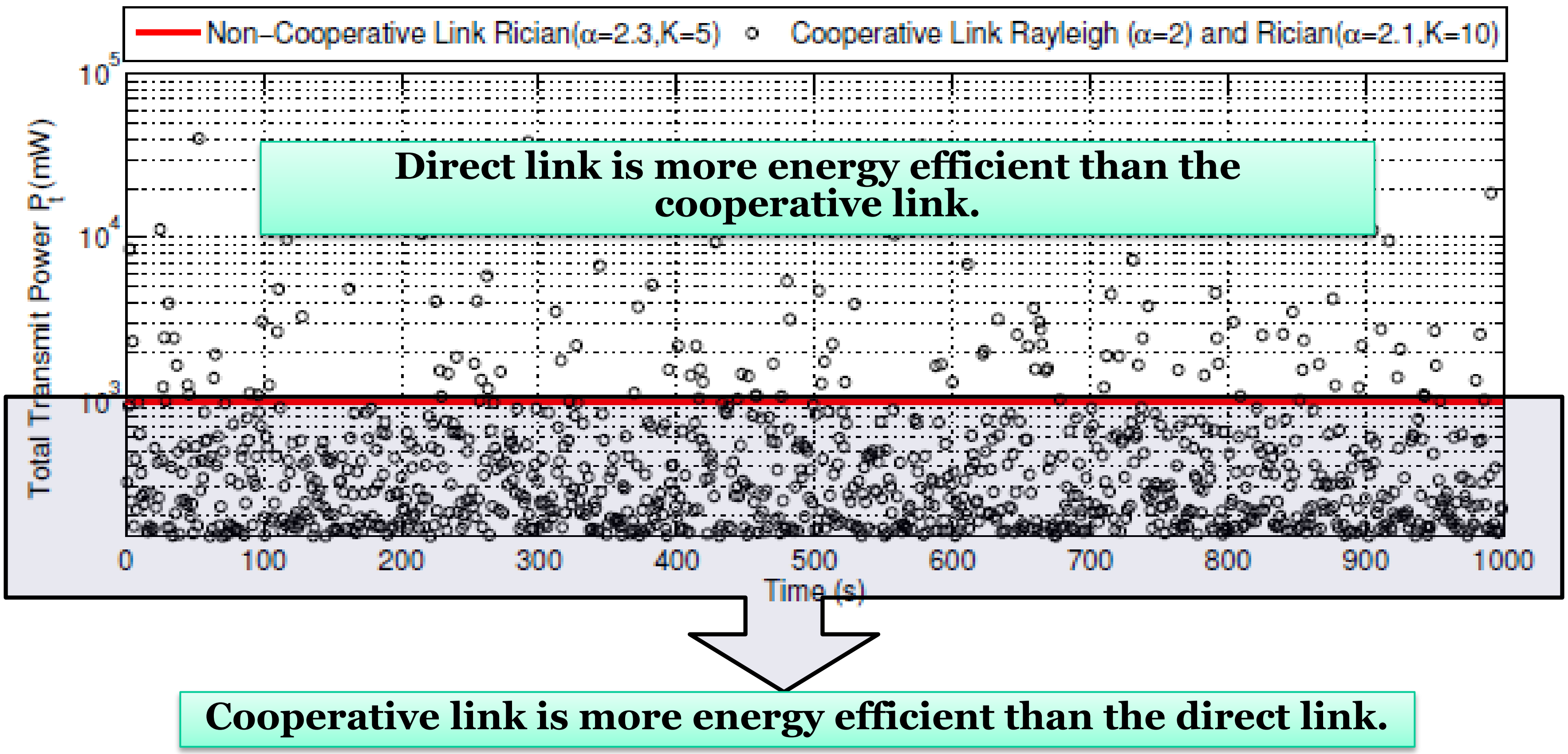
Omnet++ (INETMANET framework)

| Parameter | Unit | Value |
|---|---|---|
| Duration of each run | $s$ | 1500 |
| Number of runs | | 10 |
| Playground area | $Km^2$ | 4000 |
| Number Hosts N | | 3 |
| Carrier Frequency | $GHz$ | 3.5 |
| receiver sensitivity | $dBm$ | $-110$ |
| Path loss coefficient alpha | | $(2, 2.1, 2.3)$ |
| K | $dB$ | $(5, 10)$ |
| Position Lap | $m$ | $(500, 4000)$ |
| Position Source | $m$ | $(0, 0)$ |
| Position Relay | $m$ | $(1000, 0)$ |
| Packets Send from Source | | 1000 |
| bitrate | $Mbps$ | 6 |
| Transmission Antenna Gain | $dB$ | 3 |
| Receive Antenna Gain | $dB$ | 3 |
| Thermal Noise Terrestrial-Terrestrial | $dBm$ | $-110$ |
| Thermal Noise Terrestrial-Lap | $dBm$ | $-130$ |

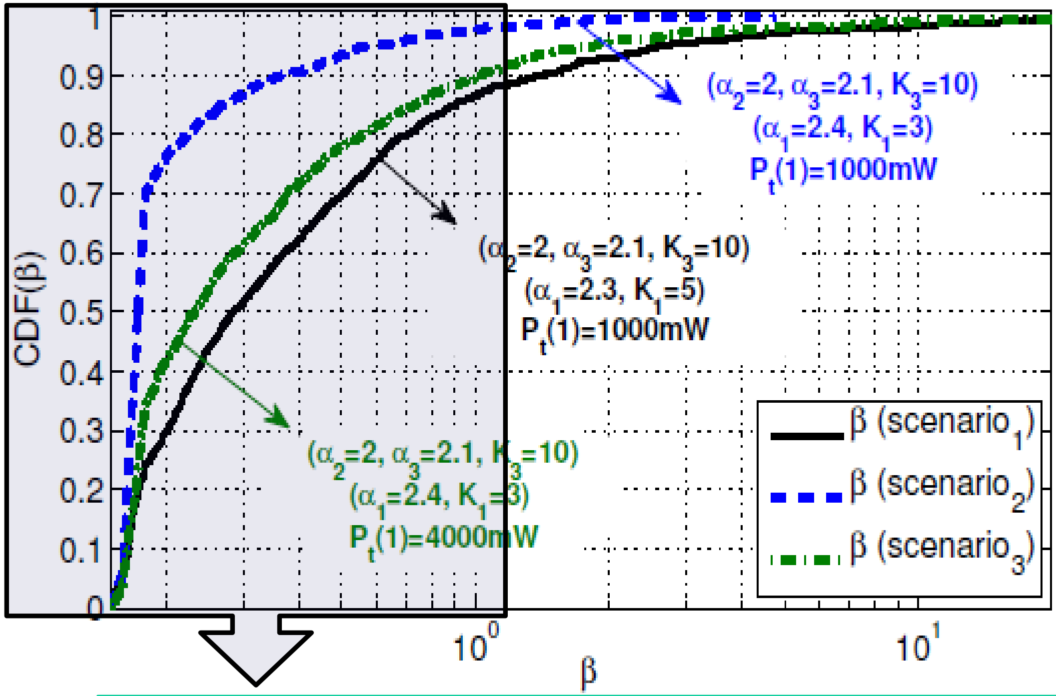


# Total transmit power calculated by the direct and cooperative links, before to apply the adaptive transmission power scheme, Vs. time (Y axis is in logarithmic scale).

**Scenario$_1$ :** Direct link worse than Cooperative link and Pt(1) = 1000mW



# Comparing the energy efficiency between direct and cooperative links by observing the cumulative distribution function of β

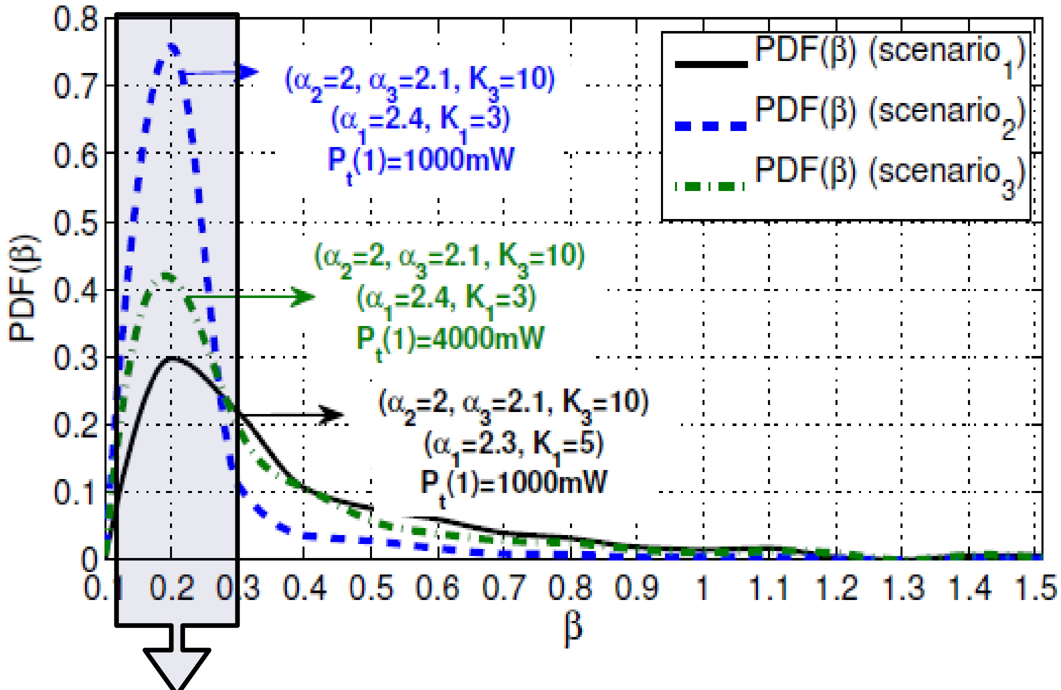



- **Scenario$_1$ :** Direct link worse than Cooperative link and Pt(1) = 1000mW
- **Scenario$_2$:** Direct link worse Direct Link from scenario1 and Pt(1) = 1000mW
- **Scenario$_3$ :** Same links conditions of scenario2 but with Pt(1) = 4000mW in order to increase the QoS.

~ **90%** of the cases the cooperative link is more energy efficient than the direct link.
~ **10%** of the cases the direct link is more energy efficient than the cooperative link.

**To implement an adaptive transmission power scheme is mandatory in order to improve the energy efficiency in the network**

# Probability Distribution Function of β




- **Scenario$_1$ :** Direct link worse than Cooperative link and Pt(1) = 1000mW
- **Scenario$_2$:** Direct link worse direct link from scenario1 and Pt(1) = 1000mW
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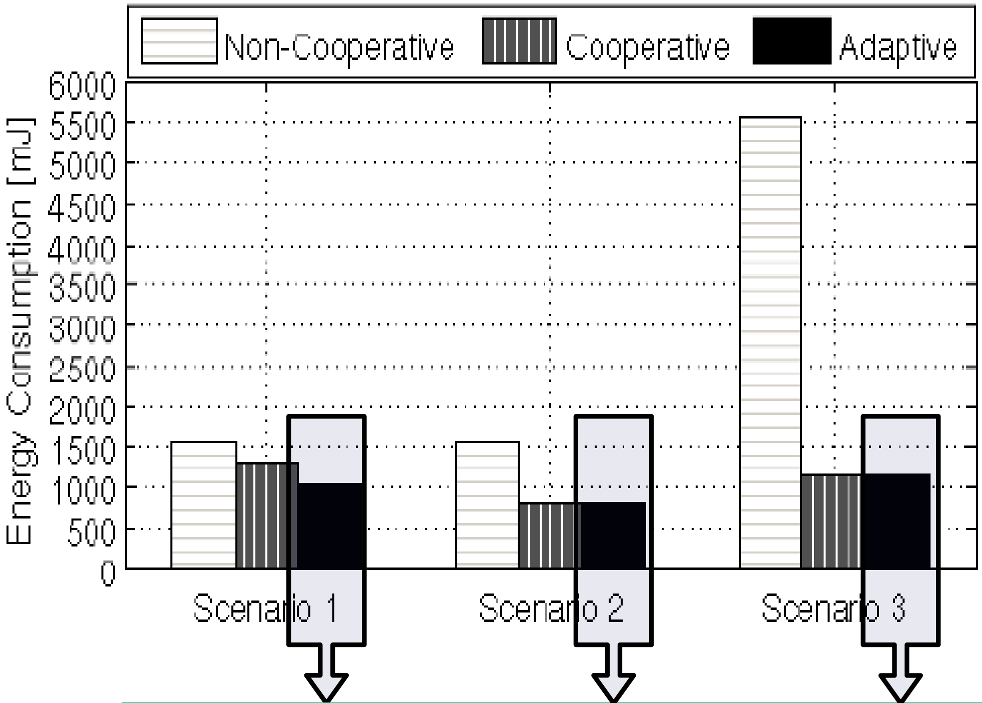
- The probability of β has smaller values is high
- The probability of cooperative link is more energy efficient than the direct link is high

# Total energy consumption of the network for the non-cooperative, cooperative and adaptive systems




- **Scenario$_1$ :** Direct link worse than Cooperative link and Pt(1) = 1000mW
- **Scenario$_2$:** Direct link worse direct link from scenario1 and Pt(1) = 1000mW
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**Adaptive transmission power scheme improves the energy efficiency in the network**

# Outline

# Conclusions and Future work

- We designed and developed a **real-time adaptive transmission scheme** which dynamically selects the best link based on the channel conditions for enabling energy efficient communications in hybrid aerial-terrestrial networks.

- We demonstrated through mathematical analysis and simulation results that the cooperation between mobile terrestrial terminals on the ground improves the energy efficiency in the uplink depending on the temporal behavior of the terrestrial and aerial uplink channels.

- We are currently extending our adaptive transmission model to analyse the energy efficiency of cooperative strategies in network topologies with multiple LAPs and multiple relay links.

ABSOLUTE

# Aerial Base Stations with Opportunistic Links for Unexpected & Temporary Evens

**http://www.absolute-project.eu**

# Final Demo

# Questions?

# Thank you for your attention

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