WIRELESS COMMUNICATIONS
PROJECT EVAL-1
MULTI-BEAM POWER ALLOCATION FOR MMWAVE COMMUNICATIONS UNDER RANDOM BLOCKAGE

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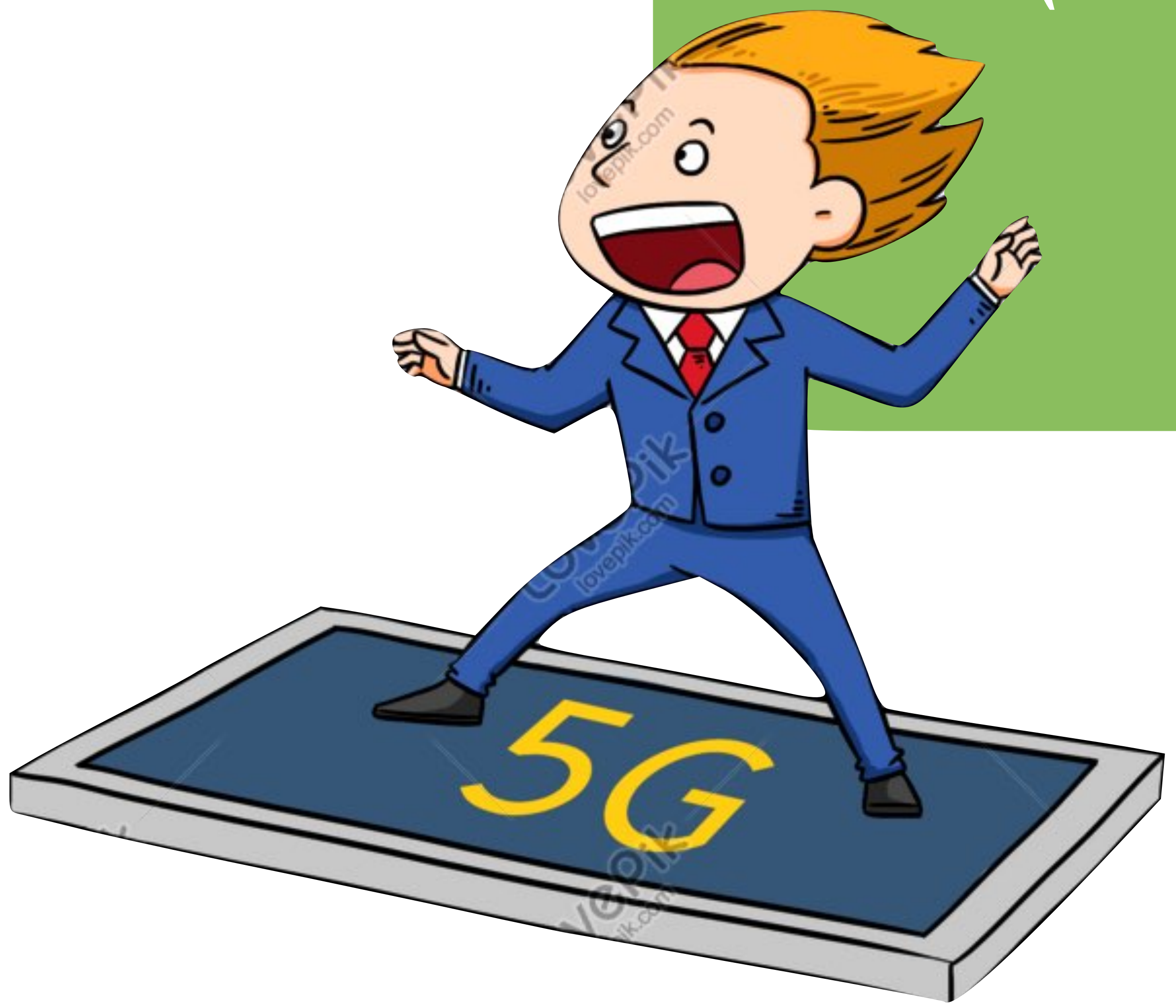
MILLIMETRE WAVE – THE COST OF HIGH DATA RATE

VERY HIGH DATA RATE (GBPS)

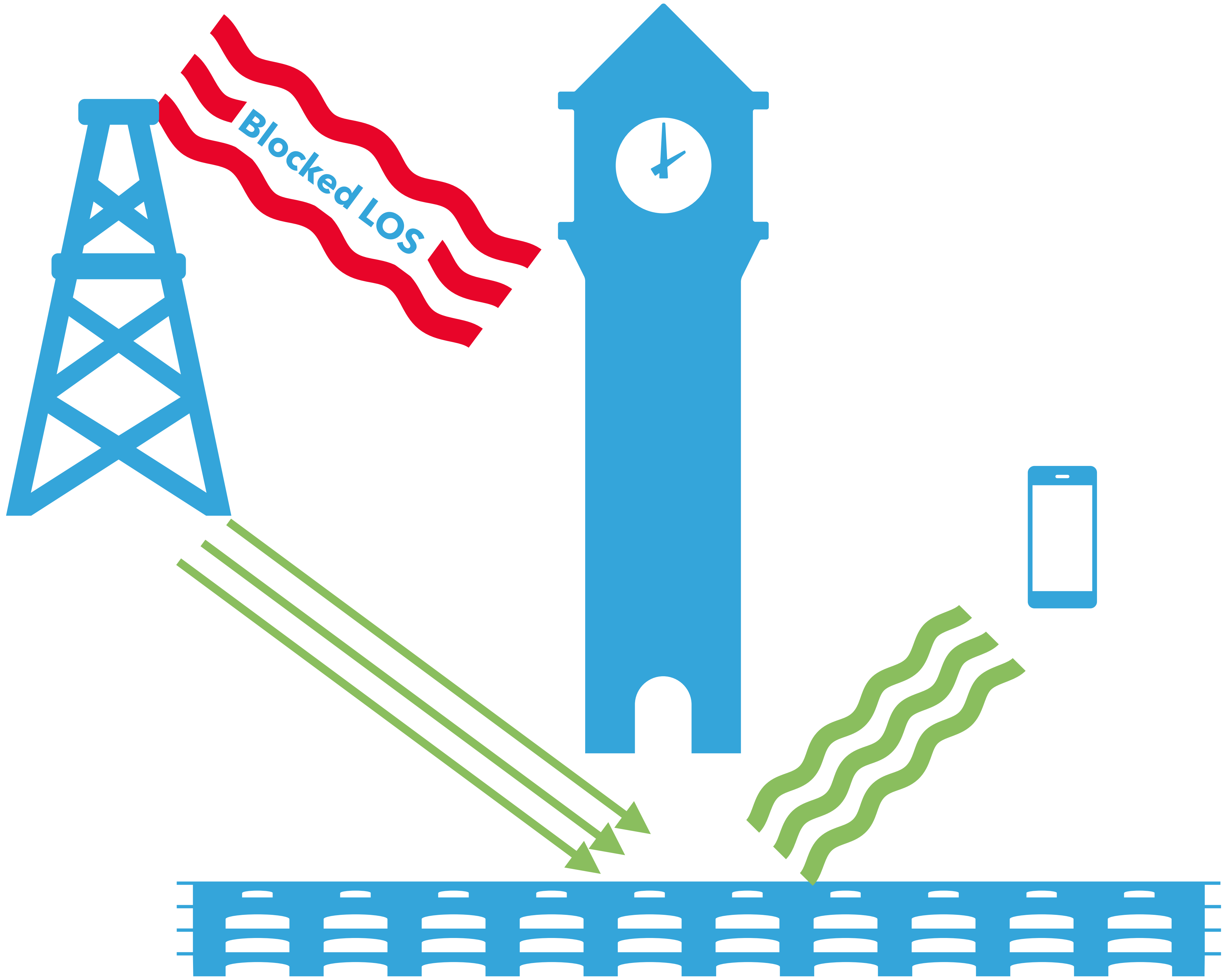


VS

HIGHLY SUSCEPTIBLE TO BLOCKAGE

FINDING THE MIDDLE GROUND – REFLECTING THE SIGNAL

- In case a direct line- of-sight communication path becomes blocked, communication via a reflected path may allow to maintain connectivity.
- A common approach is to switch to such an alternative path whenever the first path becomes blocked



NOT THE MOST EFFICIENT SYSTEM

Detecting blockage

Using the new path incurs latency

Reconfiguring transceiver

For traffic with strict latency or reliability requirements, or in highly dynamic environments where path switching would be frequent, using both paths concurrently can be more beneficial.

PAPER PROPOSES A BETTER SYSTEM

- In this paper, the authors consider using **multiple paths and dividing the transmission power over those paths, instead of path switching**
- They propose an algorithm to allocate power among the different mmWave communication paths to overcome link blockage under randomly distributed obstacles.
- Finally the performance of the proposed algorithm via simulation for various wireless environments.
- Assumption: Obstacles are modelled as a disk with radius r_d, and are assumed to be independently and randomly located. The distribution of the centres of obstacles follows a homogeneous Poisson distribution with density λ in two dimensional space, which is expressed as

$$\Pr\{k \text{ obstacles in in area } A\} = (\lambda A)^k \frac{e^{-\lambda A}}{k!}$$

ANALYSING LINK CAPACITY - BLOCKAGE PROBABILITY

- Here we formulate the probability of the path that will be taken by the signal, by considering the corresponding the **area through which it passes**. Here **1** is the direct path and **2** is reflected path. So, there are three possibilities:
    - Signal takes only the direct path
    - Signal takes only the reflected(optimum) path
    - Signal takes both direct and reflected(optimum) path

BLOCKAGE IMPACT ON RECEIVER POWER

- Formula for power at receiver - $P_{\mathrm{rx}} = KP_{\mathrm{tx}}l^{-\alpha}\beta = KP_{\mathrm{Tot}}pl^{-\alpha}\beta,$
  - K is a constant
  - P_{tot} is the total power of transmitter. P_{tx} is transmit power of the antenna
  - $p = P_{tx}/P_{tot}$
  - l is path length; α is attenuation exponent; β is reflection coefficient of reflector
- Receiver Power is sum of powers from both the direct and the reflected(optimum) path. $P_{\mathrm{rx}} = K_1P_{\mathrm{Tot}}p_1l_1^{-\alpha} + K_2P_{\mathrm{Tot}}p_2l_2^{-\alpha}\beta.$

BLOCKAGE IMPACT ON CHANNEL CAPACITY

- There are 4 possible cases:

1. Only direct path available
2. Only optimal reflected path available

SINR (signal-to-interference-and-noise-ratio) $\gamma = \frac{P_{\mathrm{rx}}}{I+N}$

3. Direct & reflected path available (SINR) $\gamma_{12} = \dfrac{K_1 P_{\mathrm{Tot}} p_1 l_1^{-\alpha} + K_2 P_{\mathrm{Tot}} p_2 l_2^{-\alpha} \beta}{I + N}$
4. Both are not available - SINR **γ** is 0

*p_1 is power ratio allocated to direct path and p_2 is

BLOCKAGE IMPACT ON CHANNEL CAPACITY

- So, we can get channel capacity **C** using law of total expectation

$$
\begin{aligned}
&E[C] \\
&= E[C|L_{1\bar{2}}]\Pr(L_{1\bar{2}}) + E[C|L_{\bar{1}2}]\Pr(L_{\bar{1}2}) + E[C|L_{12}]\Pr(L_{12}) \\
&= \rho_{1\bar{2}}\log\left(\gamma_{1\bar{2}} + 1\right) + \rho_{\bar{1}2}\log\left(\gamma_{\bar{1}2} + 1\right) + \rho_{12}\log\left(\gamma_{12} + 1\right) \\
&= \rho_{1\bar{2}}\log\left(\gamma_1 p_1 + 1\right) + \rho_{\bar{1}2}\log\left(\gamma_2 p_2 + 1\right) \\
&+ \rho_{12}\log\left(\gamma_1 p_1 + \gamma_2 p_2 + 1\right),
\end{aligned}
$$

- $L_{12'}$ is event for only direct path is available
- $L_{1'2}$ is event for only reflected path available
- L_{12} is the even for both direct and reflected path being available

OPTIMAL POWER ALLOCATION ALGORITHM

- The formula for expected capacity can be further simplified as ($p_1+p_2 = 1$):

$$\begin{aligned} f(p_1) &= \rho_{1\bar{2}} \log(\gamma_1 p_1 + 1) + \rho_{\bar{1}2} \log(\gamma_2(1 - p_1) + 1) \\ &\quad + \rho_{12} \log(\gamma_1 p_1 + \gamma_2(1 - p_1) + 1), \\ &= \rho_{1\bar{2}} \log(\gamma_1 p_1 + 1) + \rho_{\bar{1}2} \log(-\gamma_2 p_1 + \gamma_2 + 1) \\ &\quad + \rho_{12} \log((\gamma_1 - \gamma_2) p_1 + \gamma_2 + 1). \end{aligned}$$

- The log function is strictly concave. Therefore f(.) is concave wrt p_1. Therefore we can find the optimal value of p_1 using convex optimisation.

$$\begin{aligned} p_1^* &= \underset{p_1}{\operatorname{argmax}} f(p_1) \\ &\text{subject to } 0 \leq p_1 \leq 1. \end{aligned}$$

NUMERICAL ANALYSIS

- The paper then proceeds to apply its power allocation algorithm to a real example. The constants (such as location of source/reflector/receiver, obstacle distribution density, etc) are assumed.
- For two positions of reflector, the changes in link capacity against p_1 are studied.
- Then, the values of optimal power allocation are studied against the position of source, different obstacle diameters, different obstacle density, and different reflection coefficients (of reflector)