Coexistence of DSRC and C-V2X communication: modeling a competing scenario

PIMRC 2021

Blanca Ramos Elbal, *Markus Rupp*

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Technische Universität Wien

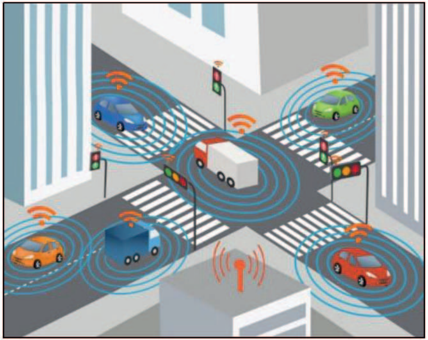
Institute of Telecommunications

Contents

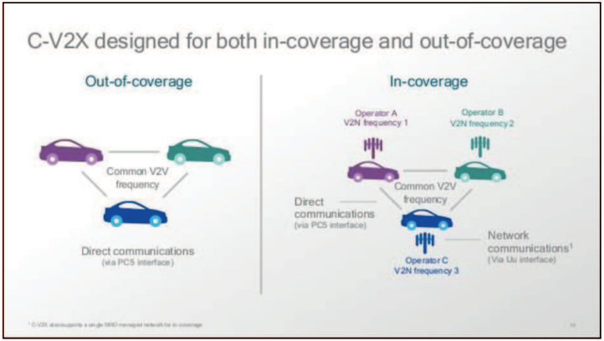
Motivation

Current vehicular Radio Access Technologies (RATs):

- Dedicated short-range communications (DSRC) / 802.11p.
- Cellular V2X (C-V2X).



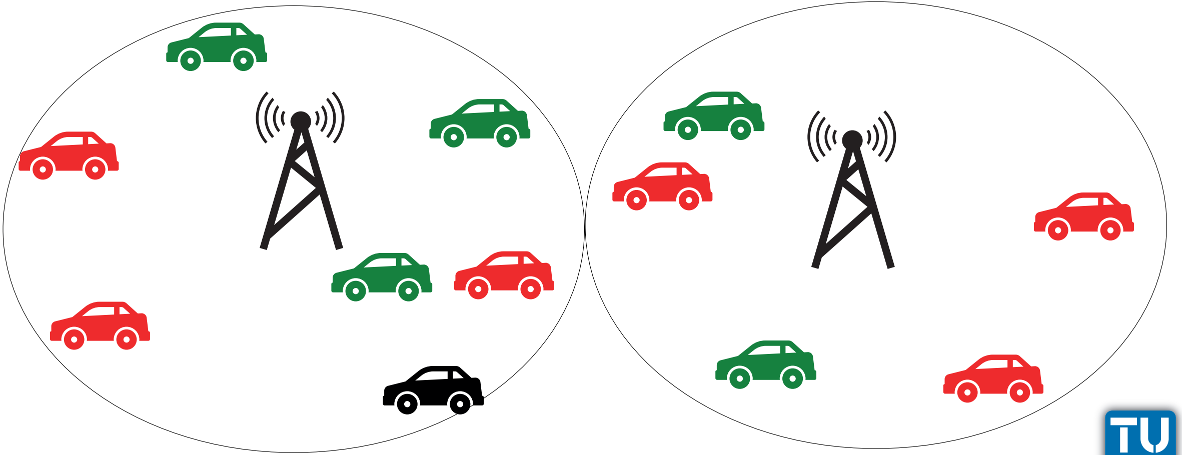
DSRC



C-V2X

Scenario: competing cellular and DSRC users

- Users divided into 2 groups:cellular users (relays and transmitters) and DSRC users.



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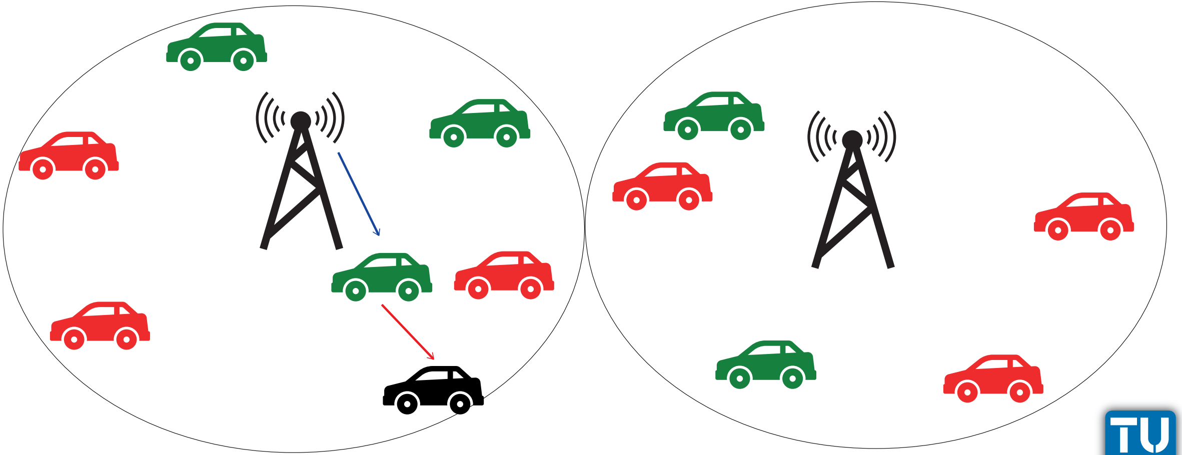

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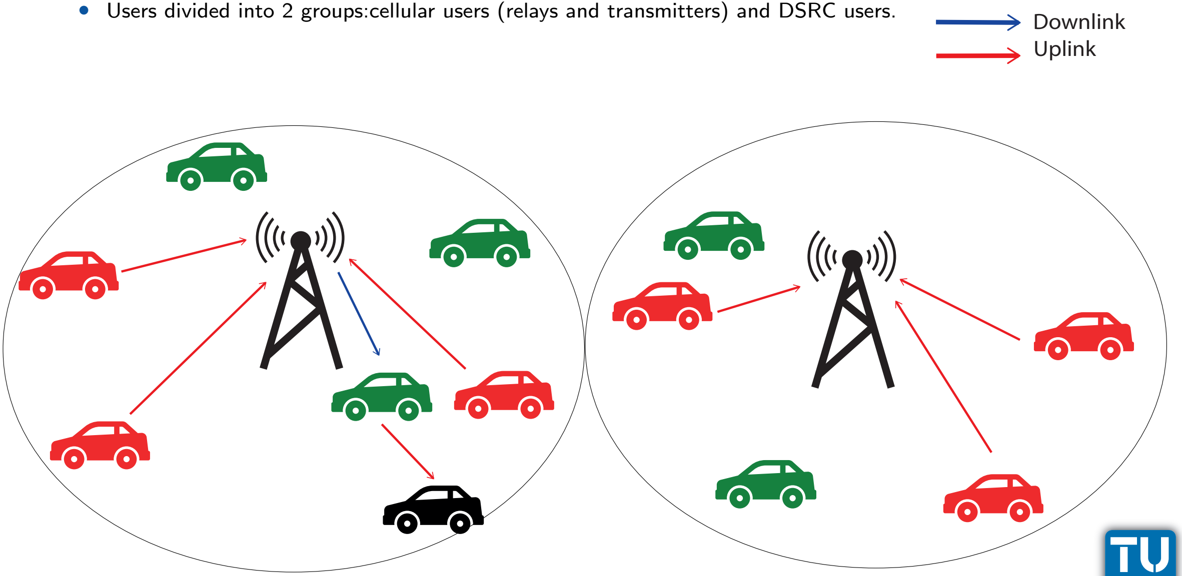

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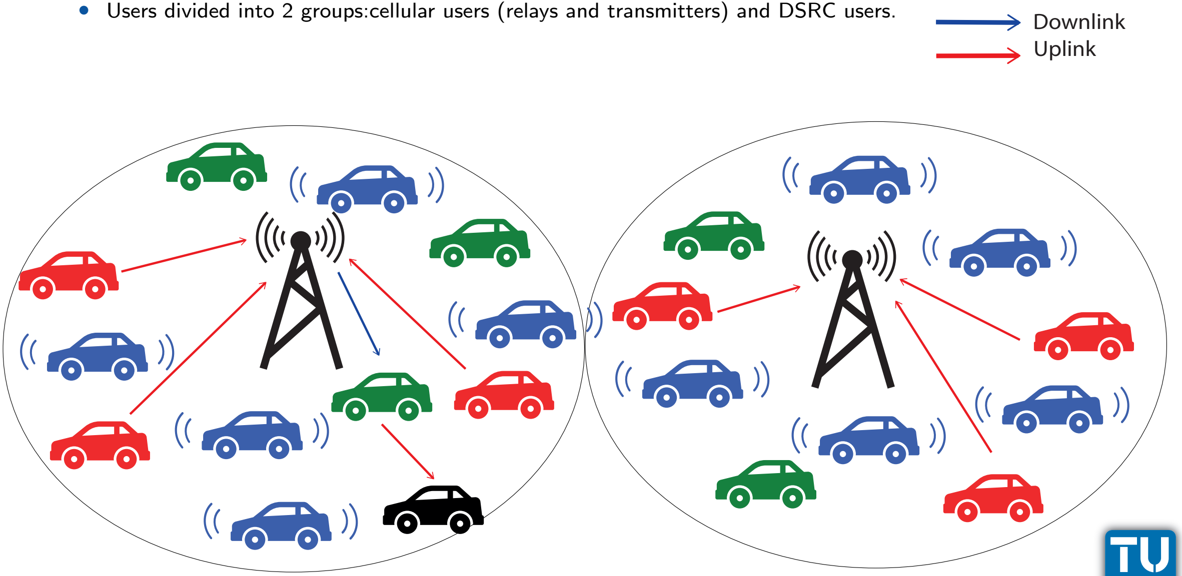
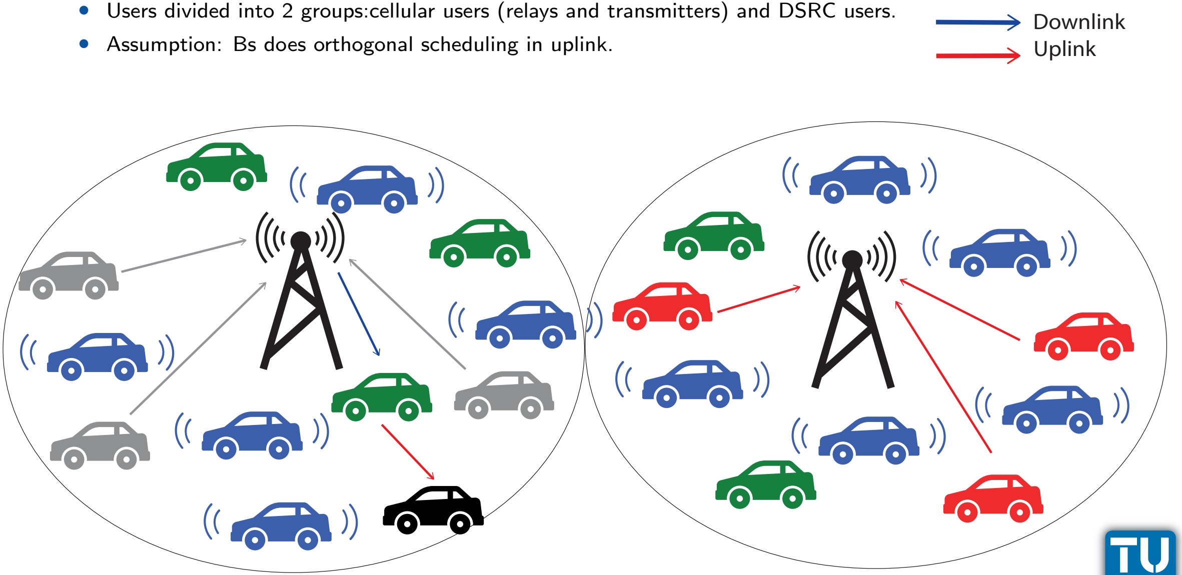


Scenario: competing cellular and DSRC users

- Users divided into 2 groups:cellular users (relays and transmitters) and DSRC users.
- Assumption: Bs does orthogonal scheduling in uplink.



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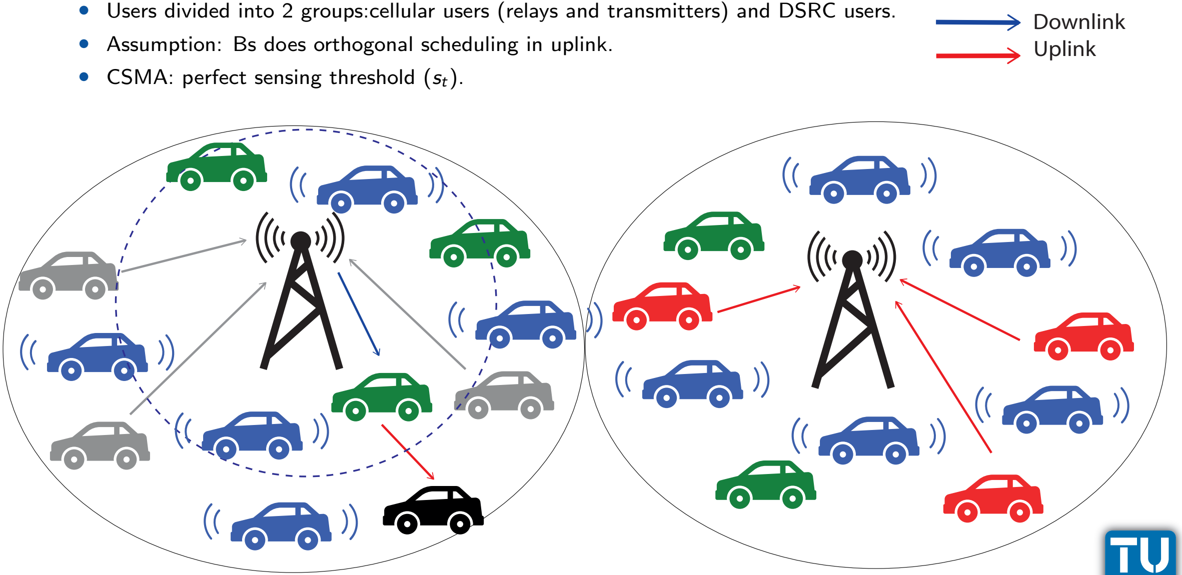

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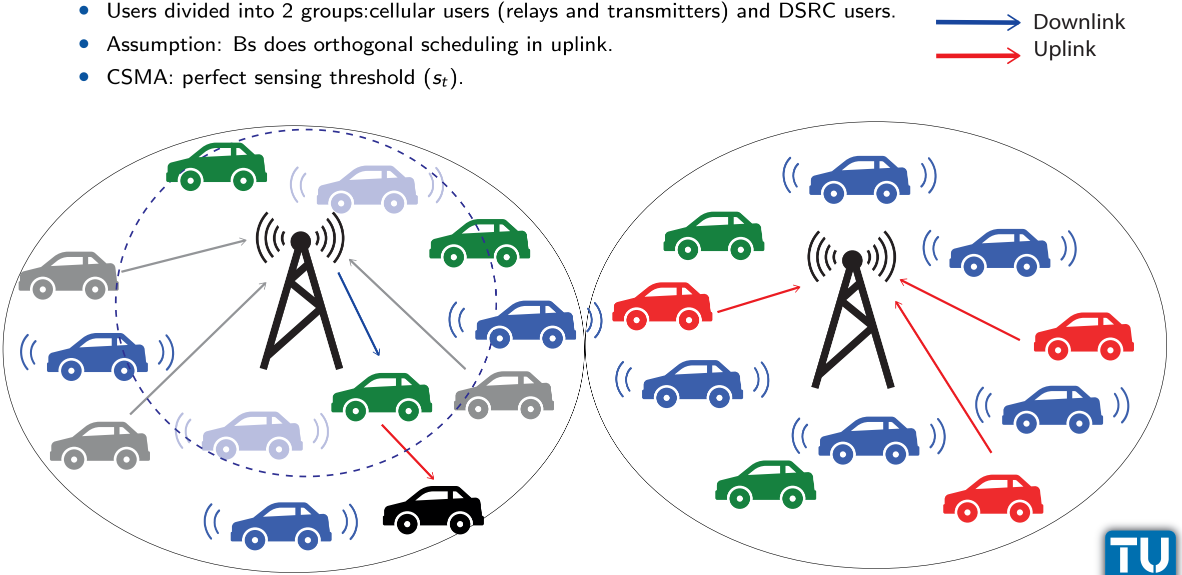

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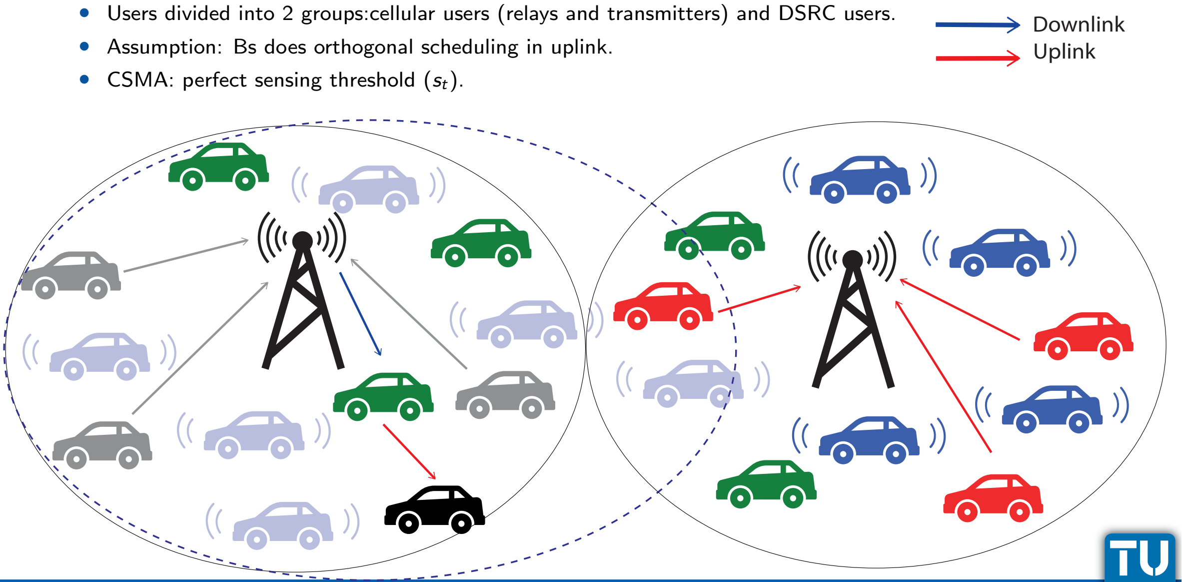

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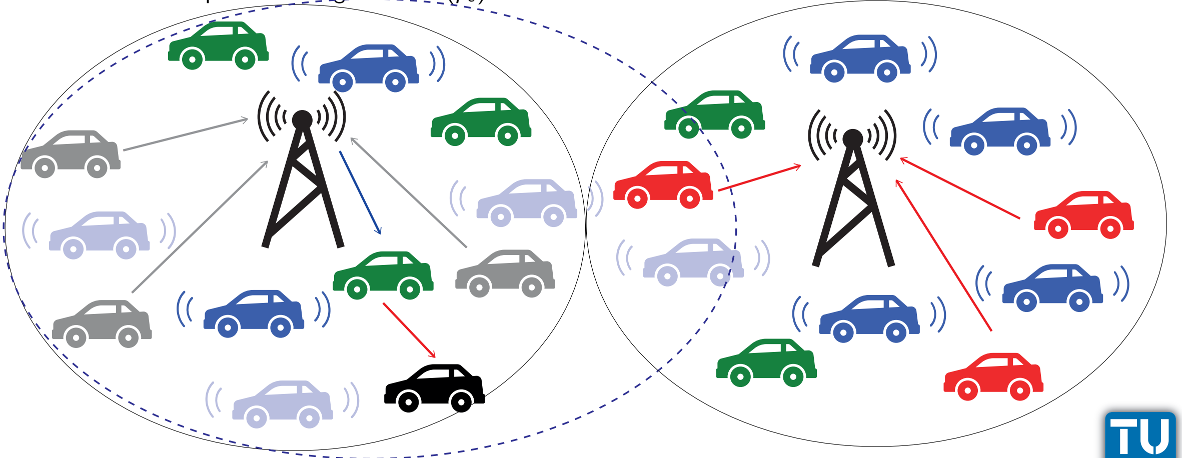

Scenario: analytical framework

Stochastic geometry to capture the randomness of wireless networks.

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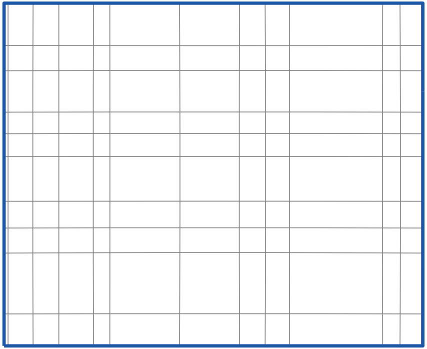
Our scenario:

- Manhattan grid $\sim$Poisson line process λ_s.



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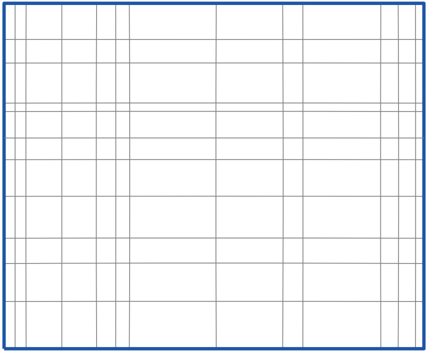

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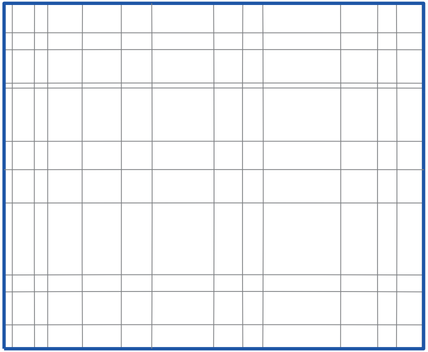

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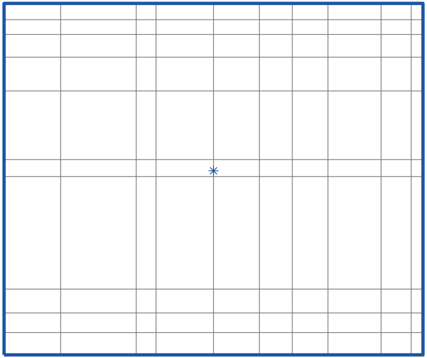

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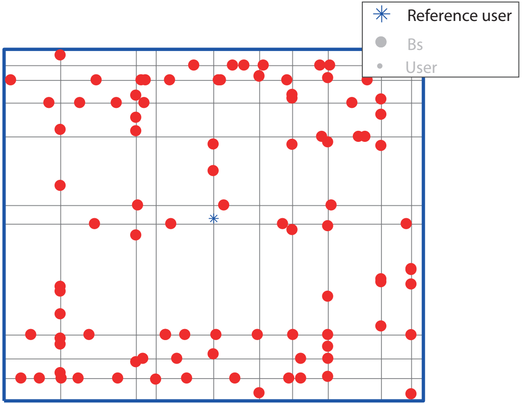

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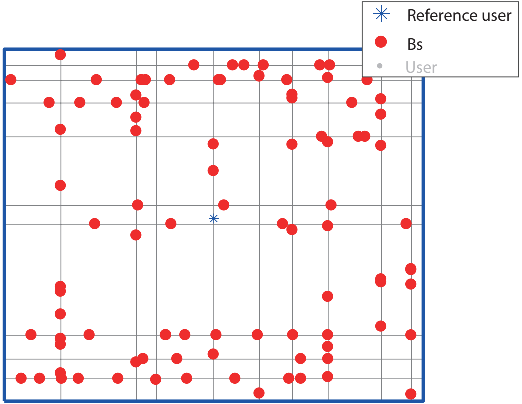

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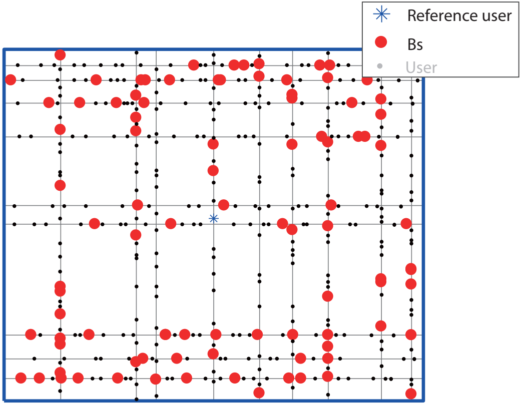

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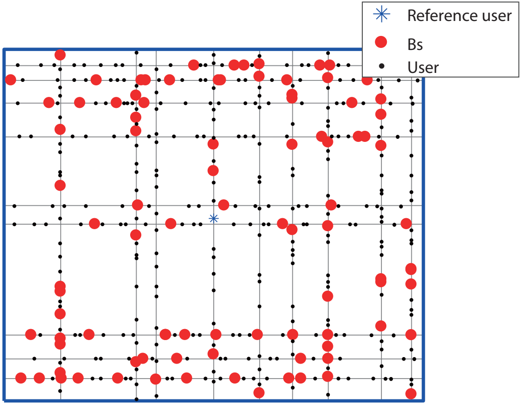

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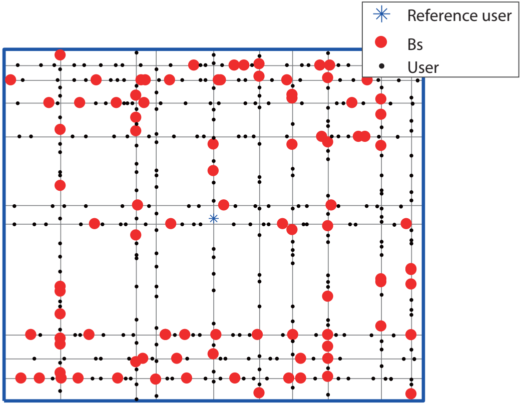
$$L_{dB}(X_s) = \beta_{dB} + \sum_{i=1}^{S} 10\alpha \log_{10}(x_i) + (S-1)\Delta_{dB}$$



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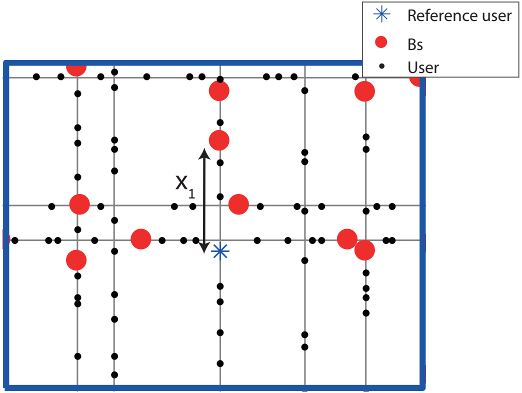

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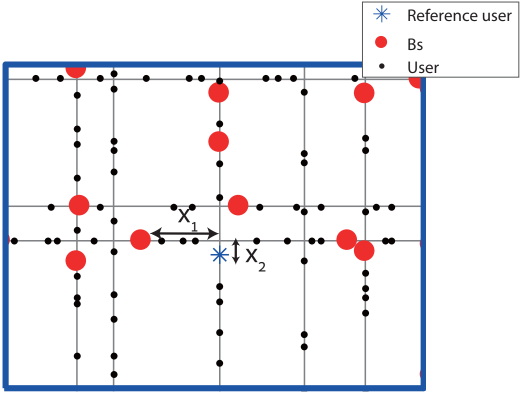

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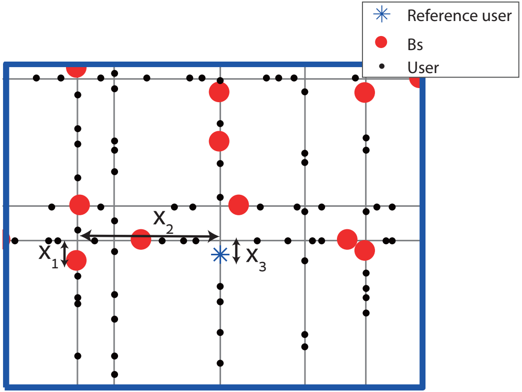

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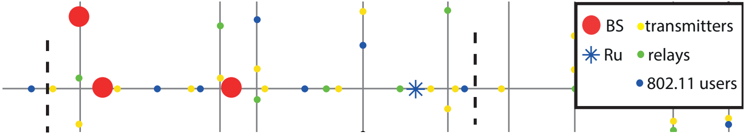

- Neglect interference from parallel streets.
- High probability to be attached to a LOS Base Station.

Φ_b Base station Poisson Point Process
Φ_s Streets Poisson Line Process

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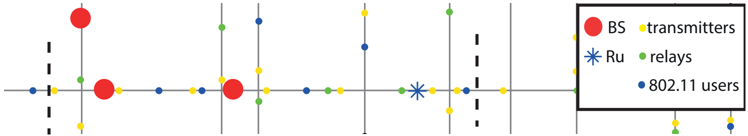

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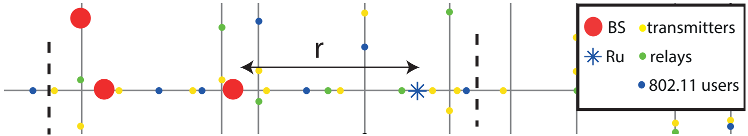

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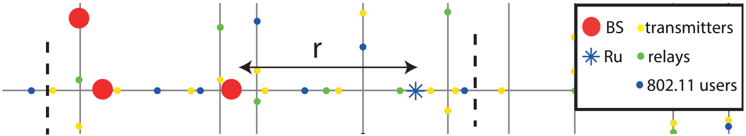

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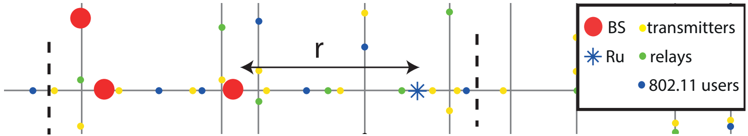

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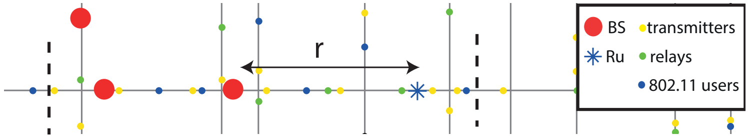

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INTERFERENCE DIFFICULT TO HANDLE

$$\gamma^{Bs-Ru} = \frac{P_{tx_b} h L(r)}{N + \underbrace{I_L^{Bs}}_{\sum_{x_{1,i}\in\Phi_b} P_{tx_b} g_i L(x_{1,i})} + \underbrace{I_N^{Bs}}_{\sum_{\substack{x_{1,j}\in\Phi_b \\ x_{2,j}\in\Phi_s}} P_{tx_b} g_j L(\{x_{1,j}, x_{2,j}\})} + I_L^{DSRC} + I_N^{DSRC}}$$

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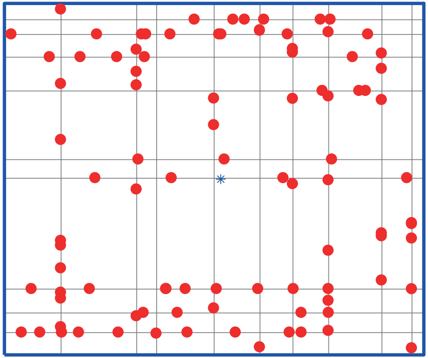

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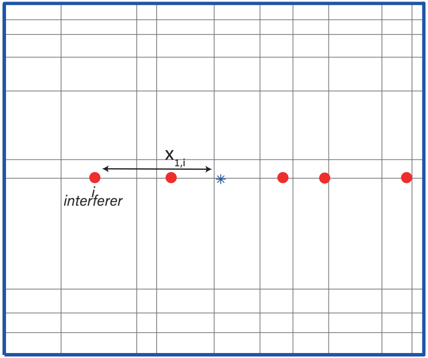

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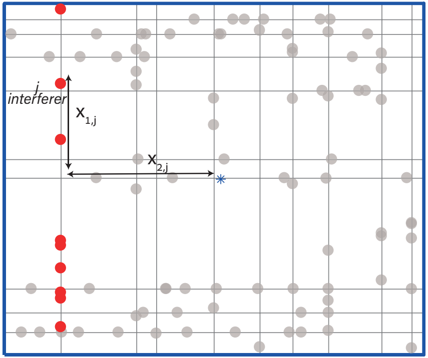

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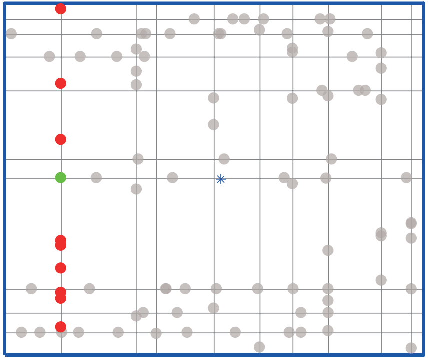
Interference mapping

- Mapping the interference of one perpendicular street to the street where the Ru is placed.



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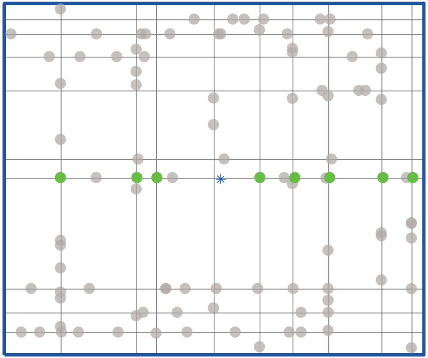
$$M^{BS} = 2\lambda_b \left(1 + \frac{1}{\alpha - 1}\right)$$



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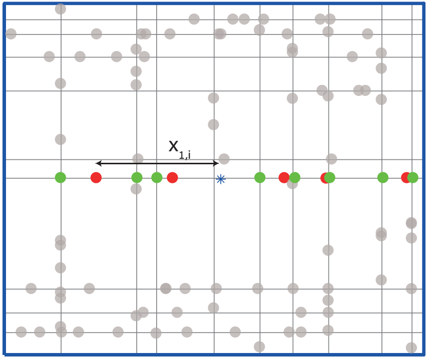

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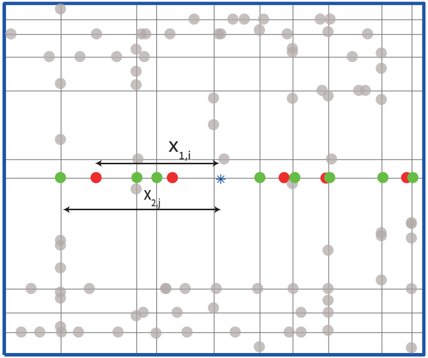

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Coverage probability

Conditioning on the BS-RU distance r, we can compute the direct link coverage probability as follows:

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&= \mathbb{P}[h > T\beta P_{tx_b}^{-1} r^{\alpha}(N + I_{BS-RU})|r] \\
&= \mathbb{E}_{I,G}[\exp(-Tr^{\alpha} P_{tx_b}^{-1}(\beta N + I_{BS-RU}))]
\end{aligned}
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$$
\begin{aligned}
I_{BS-RU} = &\sum_{x_{1,i} \in \Phi_b} g_i x_{1,i}^{-\alpha} + M^{BS}\Delta \sum_{x_{2,i} \in \Phi_s} g_i x_{2,i}^{-\alpha} \\
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Coverage probability

Conditioning on the BS-RU distance r, we can compute the direct link coverage probability as follows:

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&= \mathbb{E}_{I,G}[\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} N)\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} I_{BS-RU})]
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&= \exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} N) \\
&\underbrace{\mathbb{E}_{I,G}[\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} I_L^{Bs})]}_{\mathcal{L}_{I_L}^{BS\text{-}u}(Tr^{\alpha})} \underbrace{\mathbb{E}_{I,G}[\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} I_N^{Bs})]}_{\mathcal{L}_{I_N}^{BS\text{-}u}(Tr^{\alpha})} \\
&\underbrace{\mathbb{E}_{I,G}[\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} I_L^{DSRC})]}_{\mathcal{L}_{I_L}^{D\text{-}u}(Tr^{\alpha}\beta P_{tx_b}^{-1})} \underbrace{\mathbb{E}_{I,G}[\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} I_N^{DSRC})]}_{\mathcal{L}_{I_N}^{D\text{-}u}(Tr^{\alpha}\beta P_{tx_b}^{-1})}
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&= \mathbb{E}_{I,G}[\exp(-Tr^{\alpha} P_{tx_b}^{-1}(\beta N + I_{BS-RU}))] \\
&= \mathbb{E}_{I,G}[\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} N)\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} I_{BS-RU})] \\
&= \exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} N) \\
&\underbrace{\mathbb{E}_{I,G}[\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} I_L^{Bs})]}_{\mathcal{L}_{I_L}^{BS\text{-}u}(Tr^{\alpha})} \underbrace{\mathbb{E}_{I,G}[\exp(-Tr^{\alpha}\beta P_{tx_b}^{-1} I_N^{Bs})]}_{\mathcal{L}_{I_N}^{BS\text{-}u}(Tr^{\alpha})} \\
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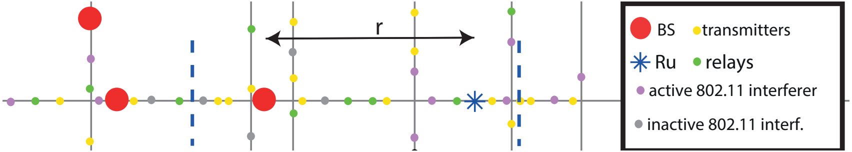
\end{aligned}
$$

Coverage probability of the direct link:

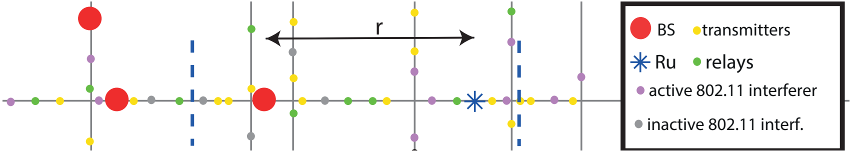
$$
P_c^{Bs\text{-}Ru}(T) = \int_0^{\infty} p_c^{Bs\text{-}Ru}(T|r) f_r(r)\,dr
$$

Coverage probability: interference bounds



$$\mathcal{L}_{I_L}^{BS\text{-}RU}(Tr^{\alpha}) = \exp\left(-2\lambda_b \int_r^{\infty} \frac{1}{1 + T^{-1}(\frac{x}{r})^{\alpha}} \mathrm{d}x\right)$$

Coverage probability: interference bounds



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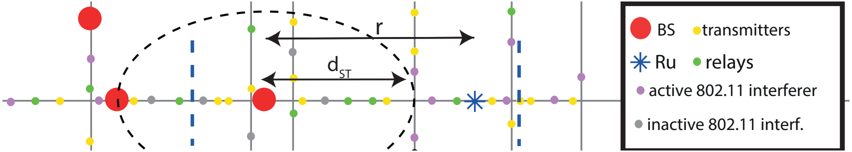
$$\mathcal{L}_{I_N}^{BS\text{-}RU}(Tr^{\alpha}) = \exp\left(-2\lambda_s \int_r^{\infty} \frac{1}{1 + (M^{BS}\Delta T)^{-1}(\frac{x}{r})^{\alpha}} \mathrm{d}x\right)$$

Coverage probability: interference bounds



$$\mathcal{L}_{I_L}^{BS\text{-}RU}(Tr^\alpha) = \exp\left(-2\lambda_b \int_r^\infty \frac{1}{1+T^{-1}(\frac{x}{r})^\alpha} \mathrm{d}x\right)$$

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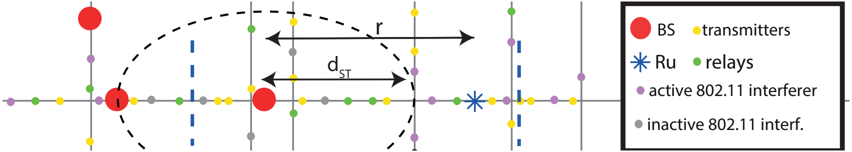
$$\mathcal{L}_{I_N}^{D\text{-}RU}(Tr^\alpha \beta P_{tx_b}^{-1}) = \exp\left(-2\lambda_d \int_r^\infty \frac{1}{1+\frac{P_{tx_b}}{P_{tx_d}}(M^d\Delta T)^{-1}(\frac{x}{r})^\alpha} dx\right)$$

Coverage probability: interference bounds



$$\mathcal{L}_{I_L}^{BS\text{-}RU}(Tr^{\alpha}) = \exp\left(-2\lambda_b \int_r^{\infty} \frac{1}{1+T^{-1}(\frac{x}{r})^{\alpha}} dx\right) \quad \mathcal{L}_{I_L}^{D\text{-}RU}(Tr^{\alpha}\beta P_{tx_b}^{-1}) = \exp\left(-2\lambda_d \int_{\mathbb{R}} \frac{1}{1+\frac{P_{tx_b}}{P_{tx_d}} T^{-1}(\frac{x}{r})^{\alpha}} dx\right)$$

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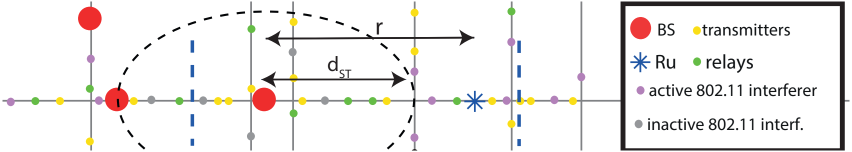
Coverage probability: interference bounds



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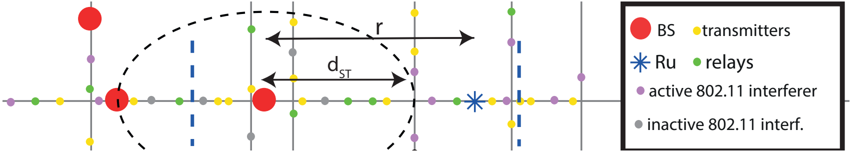
$$= \exp\left(-\lambda_d \int_{r+d_{st}}^\infty \frac{1}{1+\frac{P_{tx_b}}{P_{tx_d}}T^{-1}(\frac{x}{r})^\alpha}dx\right)$$

$$\exp\left(-\lambda_d \int_{\max(r-d_{st},0)}^\infty \frac{1}{1+\frac{P_{tx_b}}{P_{tx_d}}T^{-1}(\frac{x}{r})^\alpha}dx\right)$$

$$\mathcal{L}_{I_N}^{BS\text{-}RU}(Tr^\alpha) = \exp\left(-2\lambda_s \int_r^\infty \frac{1}{1+(M^{BS}\Delta T)^{-1}(\frac{x}{r})^\alpha}\mathrm{d}x\right)$$

$$\mathcal{L}_{I_N}^{D\text{-}RU}(Tr^\alpha \beta P_{tx_b}^{-1}) = \exp\left(-2\lambda_d \int_r^\infty \frac{1}{1+\frac{P_{tx_b}}{P_{tx_d}}(M^d\Delta T)^{-1}(\frac{x}{r})^\alpha}dx\right)$$

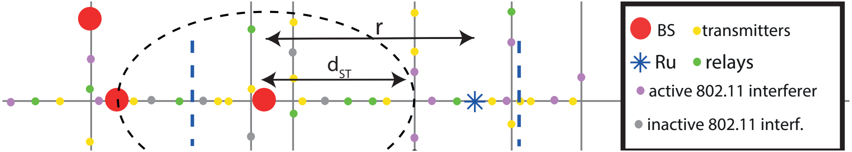
Coverage probability: imperfect sensing



Perfect sensing:

$p_c^{Bs\text{-}u}(T|r)$

Coverage probability: imperfect sensing



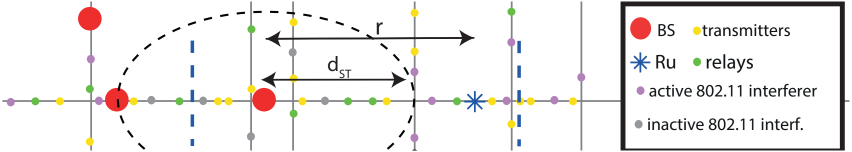
Perfect sensing:

$$p_c^{Bs\text{-}u}(T|r)$$

Imperfect sensing:

$$p_{c,p_e}^{Bs\text{-}u}(T|r) = p_c^{Bs\text{-}u}(T|r)$$

Coverage probability: imperfect sensing



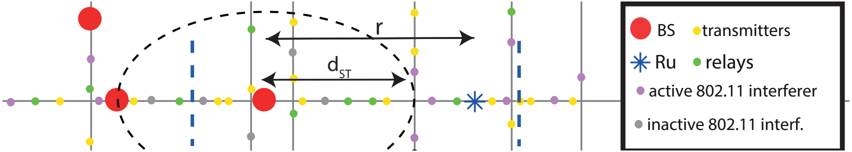
Perfect sensing:

$p_c^{Bs\text{-}u}(T|r)$

Imperfect sensing:

$$p_{c,p_e}^{Bs\text{-}u}(T|r) = p_c^{Bs\text{-}u}(T|r)\mathcal{L}_{I_L}^{Dp_e\text{-}RU}(Tr^{\alpha}\beta P_{tx_b}^{-1})$$

Coverage probability: imperfect sensing



Perfect sensing:

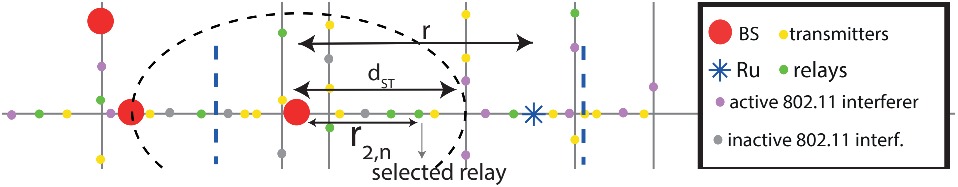
$p_c^{Bs\text{-}u}(T|r)$

Imperfect sensing:

$$p_{c,p_e}^{Bs\text{-}u}(T|r) = p_c^{Bs\text{-}u}(T|r)\boldsymbol{\mathcal{L}_{I_L}^{Dp_e\text{-}RU}(Tr^{\alpha}\beta P_{tx_b}^{-1})}$$

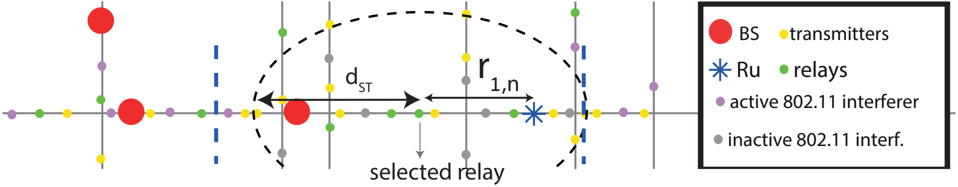
$$\mathcal{L}_{I_L}^{Dp_e\text{-}RU}(Tr^{\alpha}\beta P_{tx_b}^{-1}) = \exp\left(-2p_e\lambda_d\int_0^{d_{st}}\frac{1}{1+\frac{P_{tx_b}}{P_{tx_d}}T^{-1}(\frac{x}{r})^{\alpha}}dx\right)$$

Coverage probability: relay-assisted link



- Bs-relay link

Coverage probability: relay-assisted link



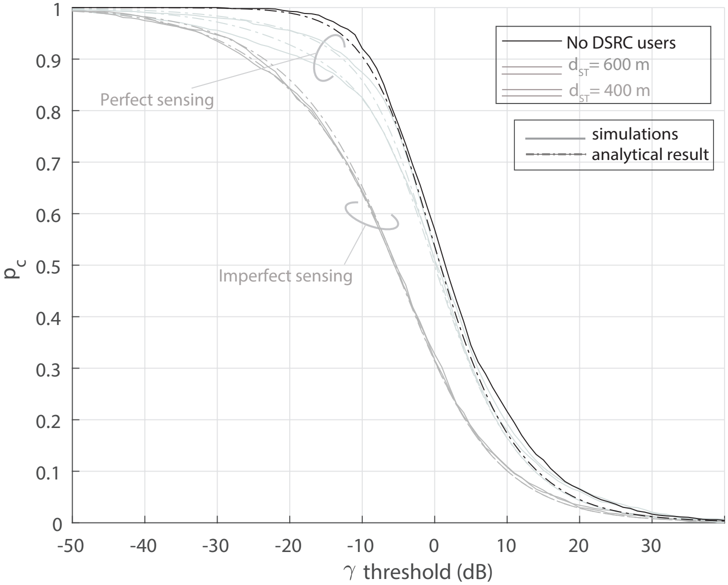
- Bs-relay link
- Relay-RU link: cell edge to exclude transmitters within the cell, sensing threshold around the relay.

Contents

Simulation parameters

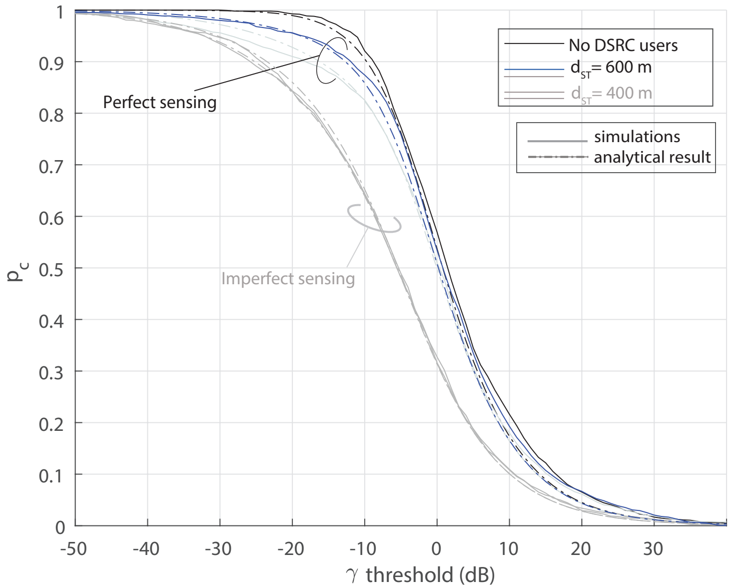
Parameter	Value
Pathloss exponent, α	2
Corner loss, Δ_{dB}	20 dB
Pathloss offset, β_{dB}	47.8 dB
Noise power spectral density, N_0	-174 dBm/Hz
Bandwidth, B	10 MHz
Fading variance, σ^2	1
Base station transmit power, P_{tx_b}	40 dBm
C-V2X user transmit power, P_{tx_u}	23 dBm
DSRC user transmit power, $P_{tx_{802.11}}$	13 dBm

Simulation



1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
p_c
-50
-40
-30
-20
-10
0
10
20
30
γ threshold (dB)
Perfect sensing
Imperfect sensing
No DSRC users
d_{ST}= 600 m
d_{ST}= 400 m
simulations
analytical result

Simulation



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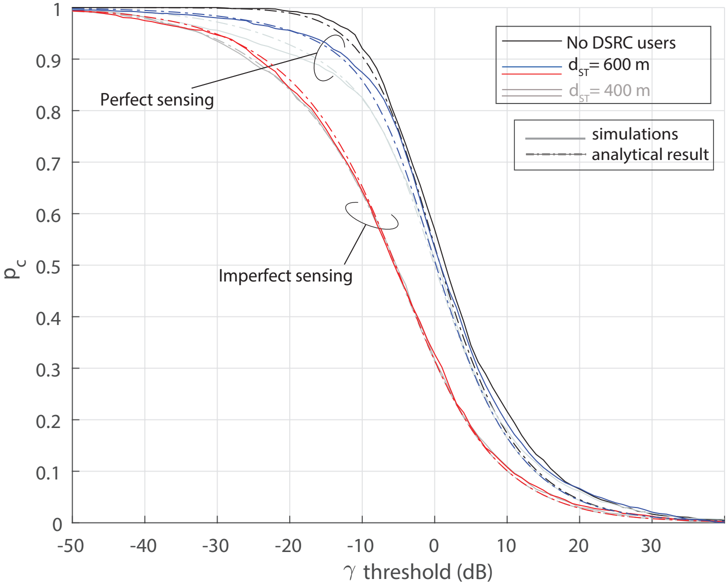

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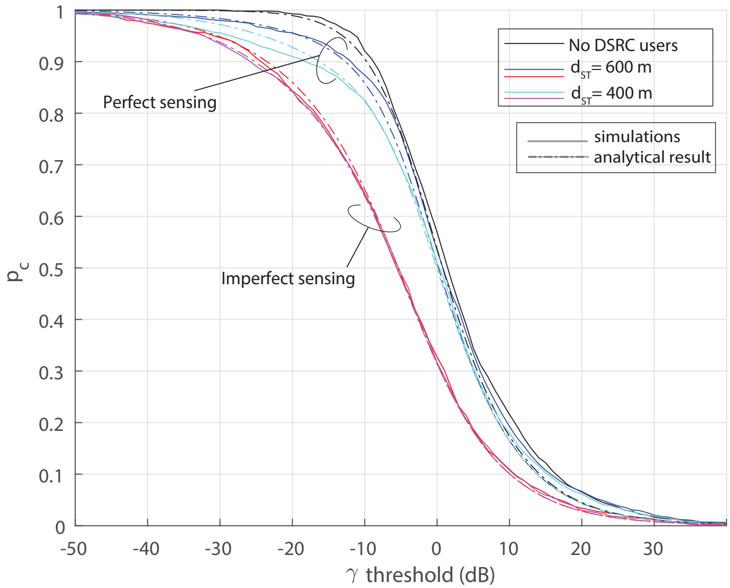

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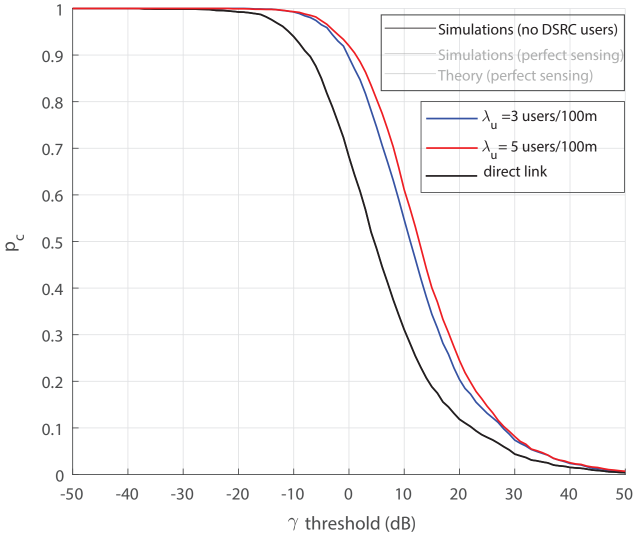
Simulation results: combined link coverage probability



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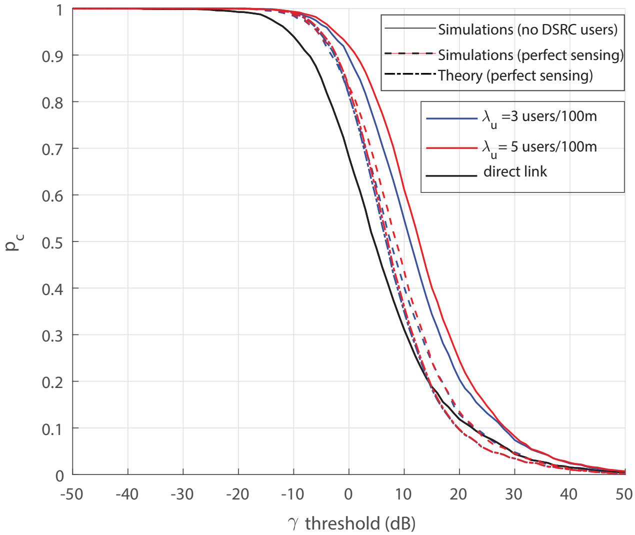

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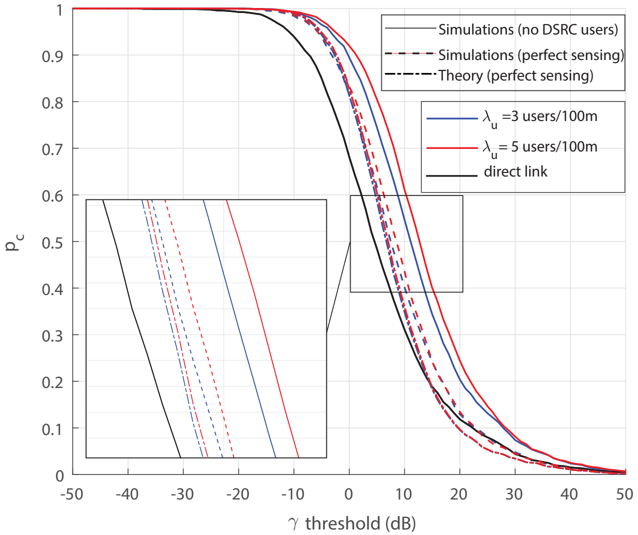

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Thank you for your attention!

bramosel@tuwien.ac.at