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Upper Bound for Energy Efficiency in Multi-Cell Fibre-Wireless Access Systems



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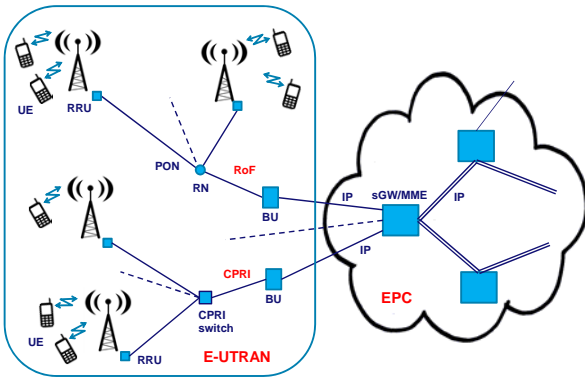
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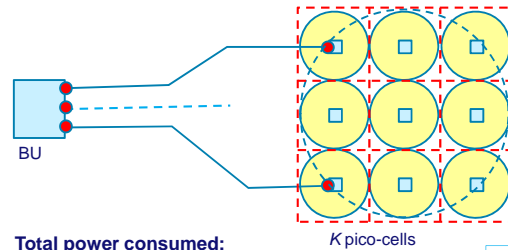
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Abstract Bringing radio access points closer to the end-users improves radio energy efficiency. However, taking into account both the radio and the optical parts of a fibre-wireless access system, the overall system energy efficiency has an upper bound determined by the relation between the energy consumption of the optical and wireless parts.

Fibre-fed LTE access



Fibre-fed radio pico-cells



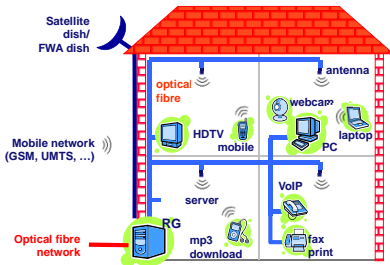
Total power consumed:

$$P_{tot, picocells} = P_{radio} + P_{optical}$$

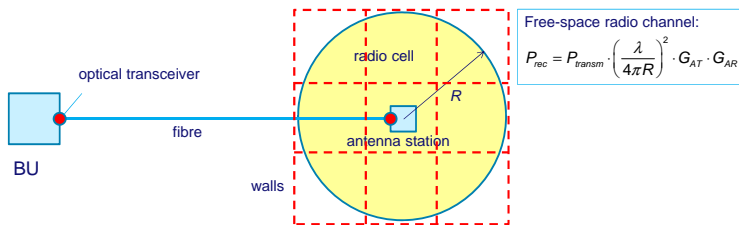
$$= c \cdot K \cdot \left(\frac{R}{\sqrt{K}}\right)^\gamma \cdot A_1^{\sqrt{N/K}-1} \cdot P_{mob} + 2 \cdot K \cdot P_{trx}$$

number of rooms N
 \geq number of pico-cells K

Wired/wireless covered indoor network



Single large radio cell



Free-space radio channel:

$$P_{rec} = P_{transm} \cdot \left(\frac{\lambda}{4\pi R}\right)^2 \cdot G_{AT} \cdot G_{AR}$$

Total power consumed:

$$P_{tot, single cell} = P_{radio} + P_{optical} = c \cdot R^\gamma \cdot A_1^{\sqrt{N}-1} \cdot P_{mob} + 2 \cdot P_{trx}$$

where

- c includes antenna gains and OE signal conversion efficiency
- N is number of rooms
- A_1 is attenuation factor per wall crossing
- γ is path loss exponent ($\gamma=2$ in free space, γ may be up to 4 or more inside buildings)
- P_{mob} is received radio power needed at mobile device
- P_{trx} is power needed in optical transceiver

Total power consumption: pico-cells vs. single cell

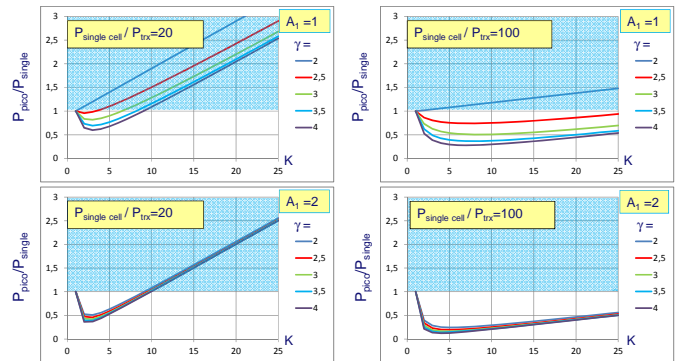
$$\frac{P_{tot, picocells}}{P_{tot, single cell}} = \frac{K^{1-\gamma/2}}{A_1^{\sqrt{N}-\sqrt{N/K}}} + \frac{2K \cdot P_{trx}}{P_{tot, single cell}} \left(1 - \frac{K^{-\gamma/2}}{A_1^{\sqrt{N}-\sqrt{N/K}}}\right)$$

is dependent on number K of pico-cells, must be <1 for total power saving. For $A_1=1$ (no walls), total power consumption is minimum for

$$K = \left[\frac{\gamma-2}{2} \left(\frac{P_s}{2P_{trx}} - 1 \right) \right]^{2/\gamma}$$

Energy savings by pico-cells

- $N=25$ rooms



Concluding remarks

- Radio-over-fiber based pico-cell techniques can improve not only the capacity but also the energy efficiency of wireless networks.
- As long as the number of pico-cells stays below an upper bound, the total power consumption of the network is less than that of a single-cell network
- Total power consumption is minimized by optimizing the number of pico-cells.
- The optimum number of picocells increases and the attainable minimum power consumption decreases when radio path loss exponent increases, wall losses increase, and/or RoF transceiver power consumption decreases.

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