Ambient Radiofrequency Power: the Impact of the Number of Devices in a Wi-Fi Network

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802.11 Networks

- Standard used for home/office wireless networks,
- Branded as *WiFi*,
- Uses ISM band at 2.4GHz (802.11b/g),
- Or maybe at 5GHz (802.11a),
- Transfers packets of data like Ethernet.
- Carrier sense multiple access protocol.

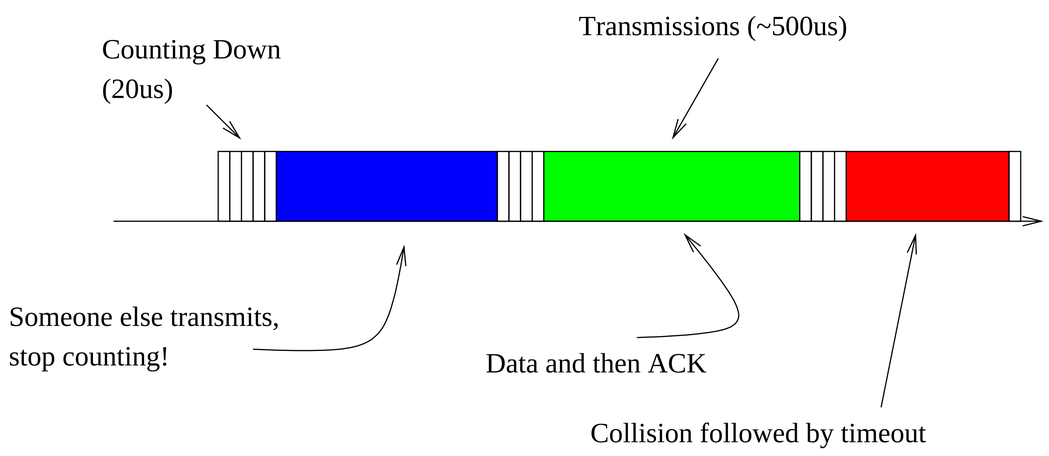
Aim: to calculate radiofrequency exposure bounds from large networks.

Complication: 802.11 MAC Layer, power is neither fixed nor simple scaling.

- After transmission choose rand(0,CW-1).
- Wait until medium idle.
- Count down in slots.
- Transmit when get to 0 (if you have a packet).
- If ACK then $CW \leftarrow CW_{min}$ else $CW \leftarrow 2CW$.

802.11 MAC Layer

802.11 MAC is randomised: concurrent transmissions are possible.



Bianchi Models

Work by Bianchi in traffic engineering has allowed the probability:

- idle states,
- successful transmissions,
- collisions.

Data throughput then calculated as:

$$\frac{D_S n\tau(1-\tau)^{n-1}}{T_I(1-\tau)^n + T_S n\tau(1-\tau)^{n-1} + T_C(1-(1-\tau)^n - n\tau(1-\tau)^{n-1})} \quad (1)$$

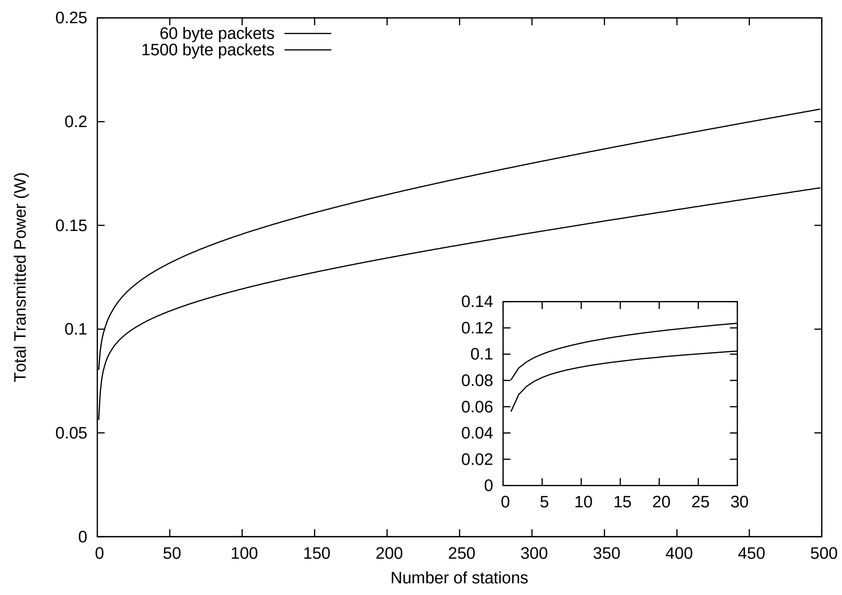
where D_S is the amount of data in a successfully transmitted packet and T_I, T_S and T_C are the times taken for an idle state, a successful transmission and a collision respectively.

We generalise to calculate probability of r stations transmitting at a time, and then calculate mean power as:

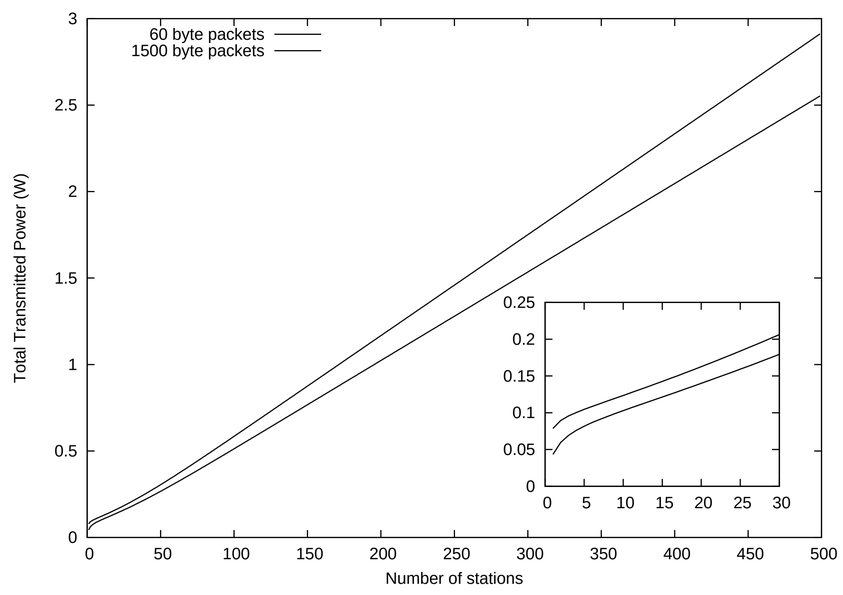
$$P = \frac{E}{T} = \frac{0(1-\tau)^n + E_S n\tau(1-\tau)^{n-1} + E_C \sum_{r=2}^{n} r\binom{n}{r}\tau^r(1-\tau)^{n-r}}{T_I(1-\tau)^n + T_S n\tau(1-\tau)^{n-1} + T_C(1-(1-\tau)^n - n\tau(1-\tau)^{n-1})}. \quad (2)$$

where E_I, E_S and E_C are the times taken for an idle state, a successful transmission and a collision respectively.

Results: Saturated Unicast Traffic



Results: Saturated Broadcast Traffic



Conclusions, Future and Related Work

Conclusions:

- ICNIRP guideline: 80mW kg^{-1} for the general public.
- ICNIRP guideline: 400mW kg^{-1} for occupational exposure.
- This is whole body exposure limits for long time periods.
- Even large unicast networks should not violate limits.
- Broadcast network effectively disables 802.11's backoff.
- Close for small person, but saturated all-broadcast network unrealstic.

Future Work:

- Experimental validation.
- Study of unsaturated networks.

Related work:

- *Radiofrequency Exposure from Wireless LANs Utilizing Wi-Fi Technology*, Kenneth R. Foster, Health Physics, March 2007, 93(3), 280–289.
- *Exposure of the general public due to wireless LAN applications in public places*, G. Schmid et al, Radiation Protection Dosimetry, 2007, 124(1), 48–52.