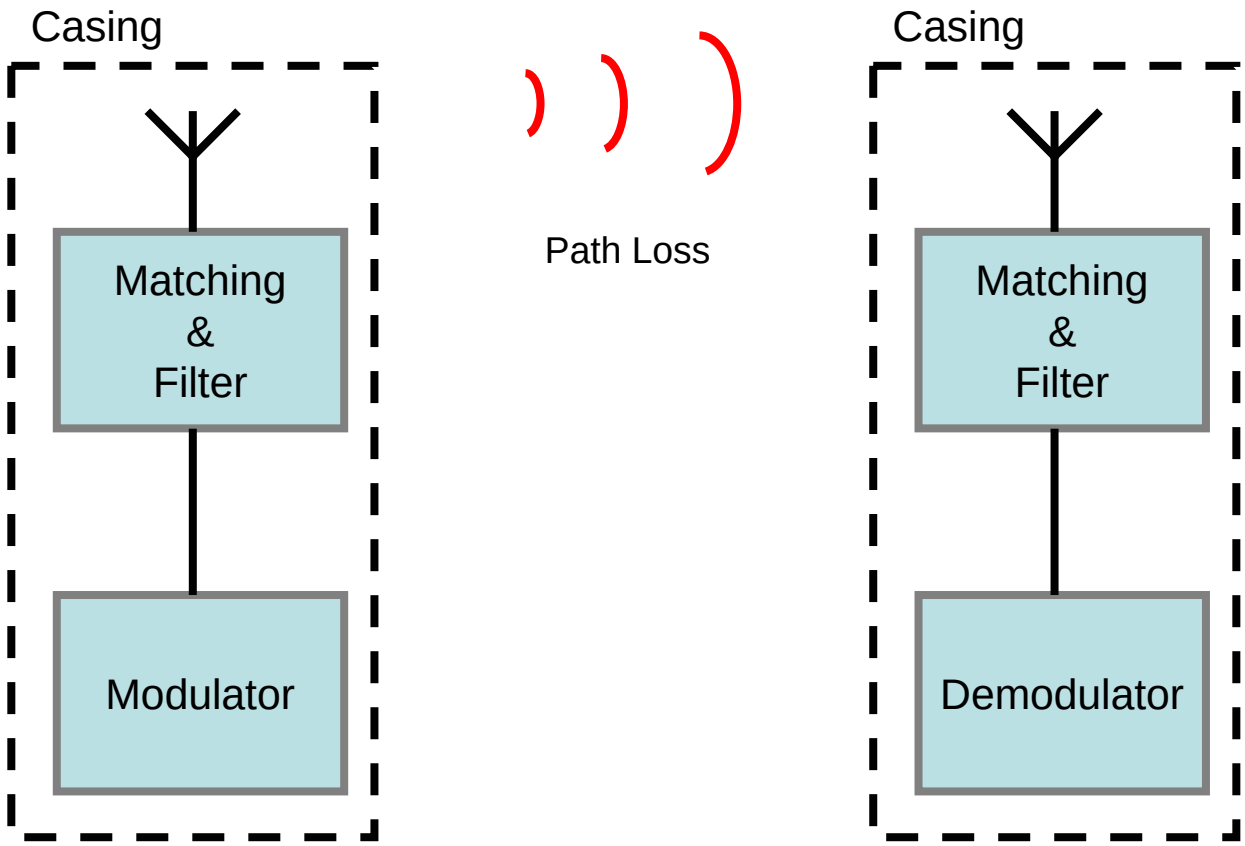
Link budget

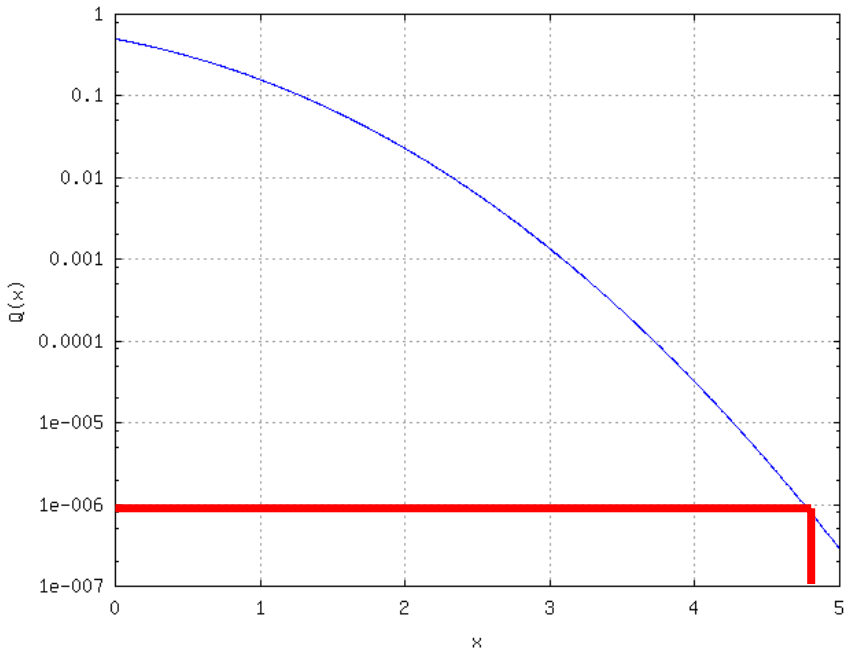
Claus Rømer Andersen

Simple transmitter and receiver

Example: 868 MHz FSK



Estimating minimum energy per bit, Eb



$$BER = Q\left(\sqrt{\frac{E_b}{k \cdot T_{eff}} \cdot \left[1 - \frac{\sin(2 \cdot \pi \cdot h)}{2 \cdot \pi \cdot h}\right]}\right)$$

- Acceptable BER defined as 10^{-6}
- h = 0.715 (modulation index)
- k = $1.38*10^{-23}$ J/K (Boltsmann's constant)
- T_{eff} = 290 K (Room temp., antenna direktiviy of 0 dBi)

➔ $E_b = 7.43*10^{-20}$ W/Hz = -161.3 dBm/Hz

Link budget for 868 MHz FSK system

Transmitter	
Tx power (dBm)	16.0
Antenna gain (dBi)	0.0
Cable losses (dB)	0.2
Casing losses (dB)	1.0
EIRP (dBm)	14.8
Demodulator	
Required Eb (dBm/Hz)	-161.3
Datarate (kbps)	220
Req. demodulator power (dBm)	-107.9
Receiver	
Req. demodulator power (dBm)	-107.9
Antenna gain (dBi)	0.0
Cable losses (dB)	0.2
Casing losses (dB)	1.0
Required received power (dBm)	-106.7

$$EIRP_{dBm} = P_{t,dBm} + G_{t,dBi} - Losses_{dB}$$

$$P_{in,dBm} = E_{b,dBm/Hz} + 10 \cdot \log(R_b)$$

$$P_{r,dBm} = P_{in,dBm} - G_{r,dBi} + Losses_{dB}$$

Link budget for 868 MHz FSK system

Propagation	
EIRP, Tx (dBm)	14.8
Required received power (dBm)	-106.7
Fast fading margin (dB)	7.5
Polarisation loss (dB)	3.0
Log normal fading margin (dB)	0.0
Building penetration loss (dB)	0.0
Max. allowed path loss (dB)	111.0

$$PL_{dB} = EIRP_{dBm} - P_{r,dBm} - Losses_{dB}$$

Max. range	
Max. allowed path loss (dB)	111.0
Frequency (MHz)	868.3
Max. range,free space - N=2 (m)	9717.1

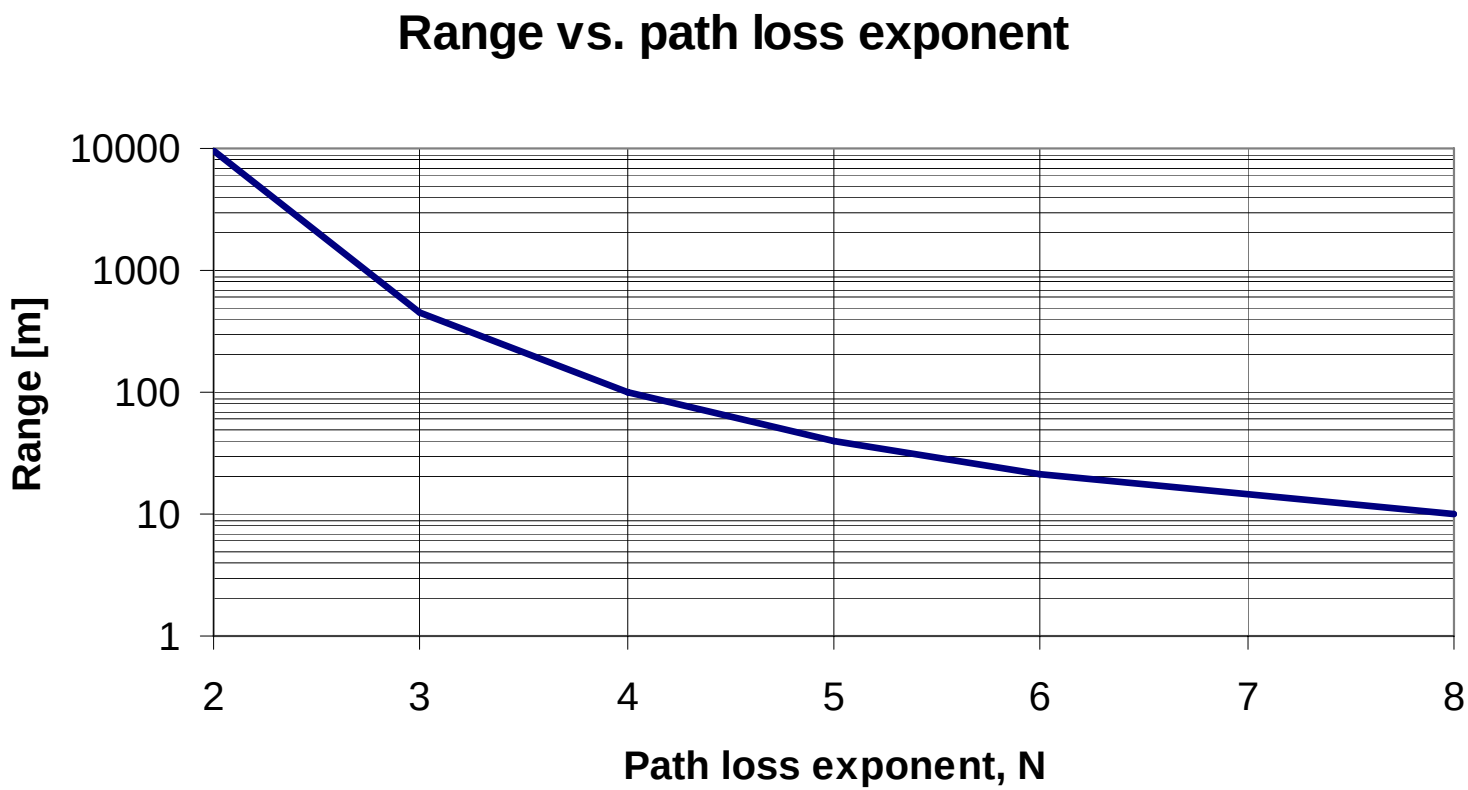
$$L_0 = \frac{(4 \cdot \pi)^2 \cdot R^N}{\lambda_0^2}$$

Almost 10 kM!

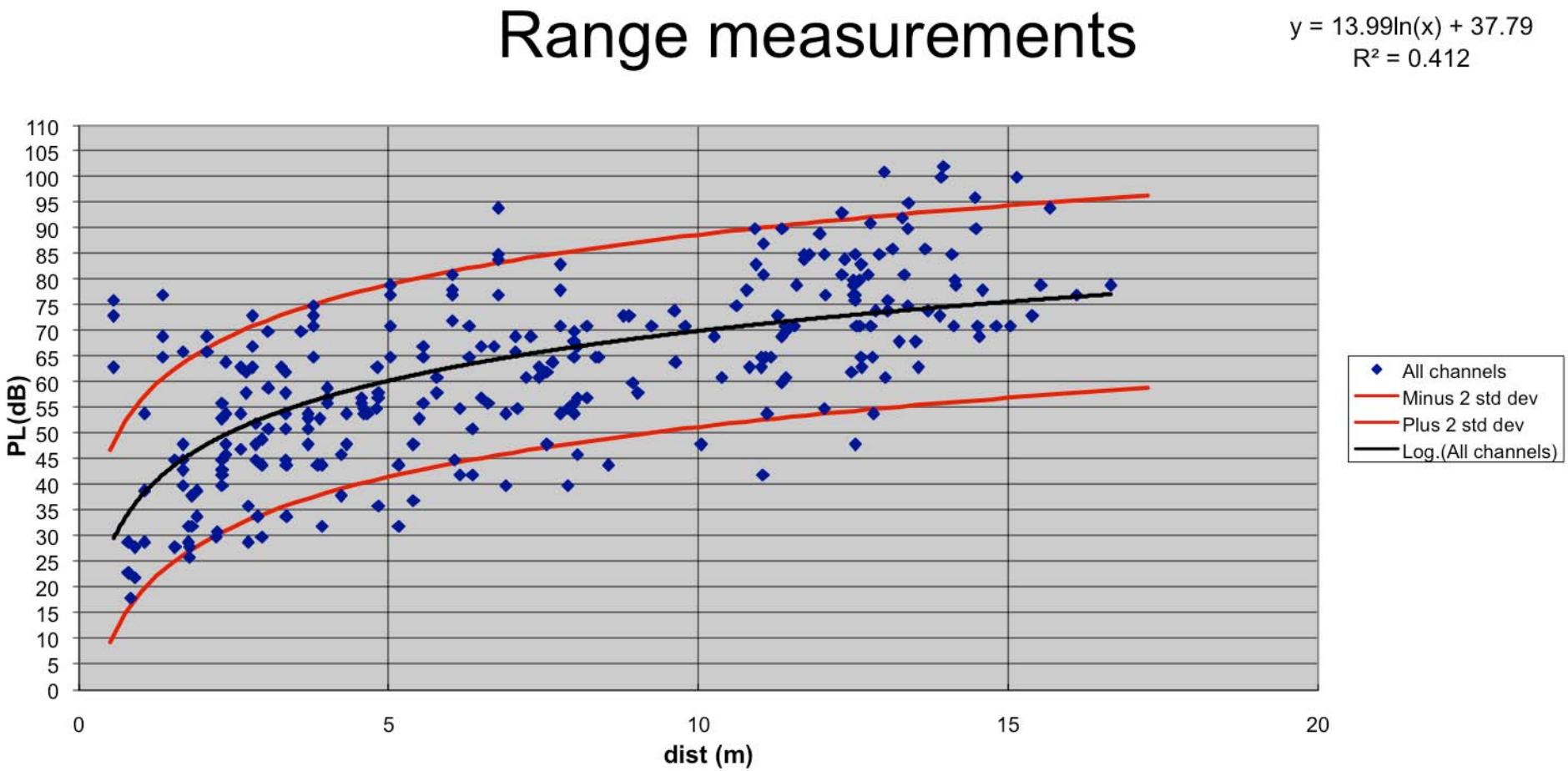
Simple non-ideal path loss model

Expected range

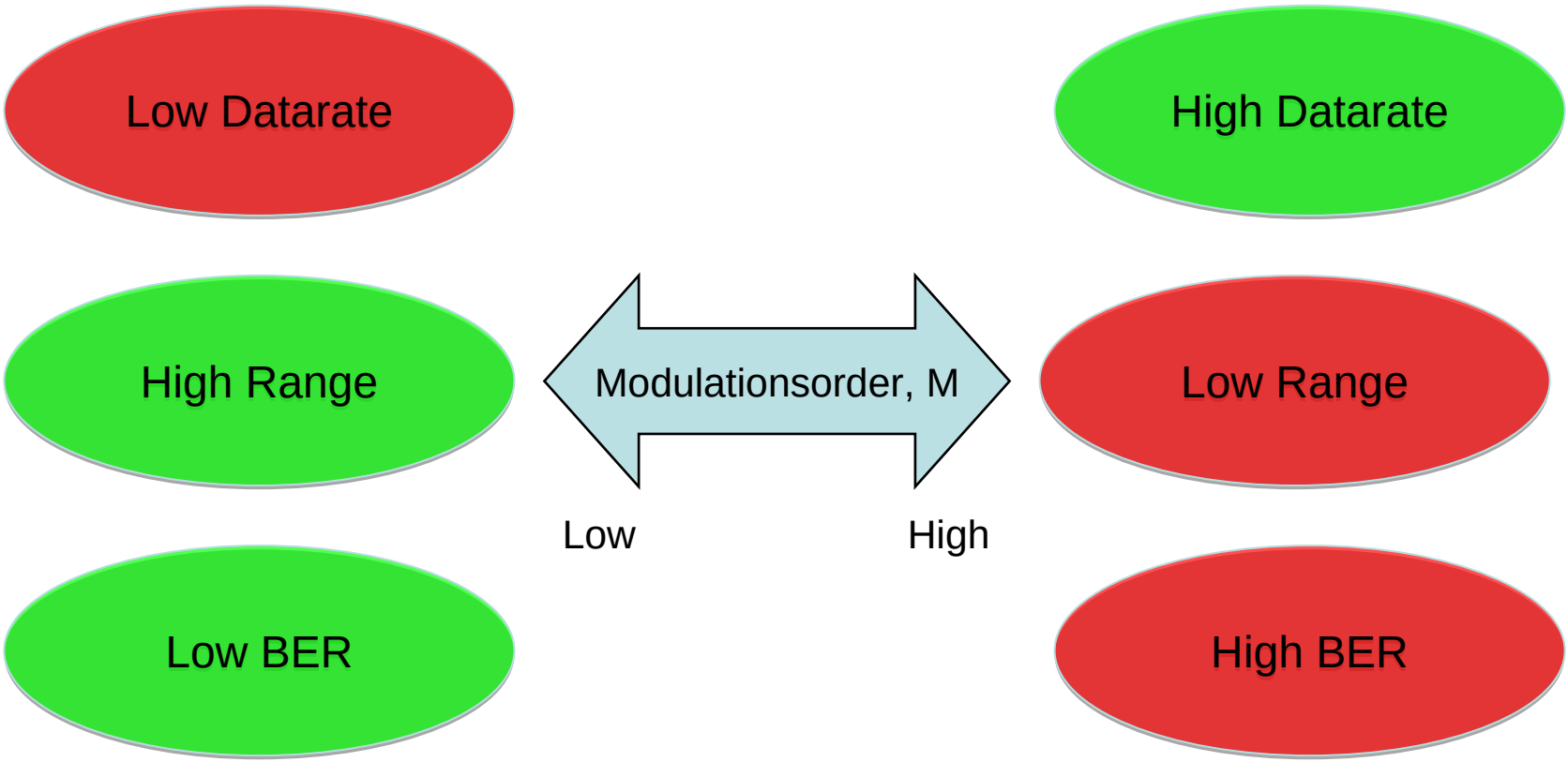
Path loss exponent (N)	2	3	4	5	6	8
Expected range (m)	9717.1	455.4	98.6	39.4	21.3	9.9



WLAN: ch. 11, 16, 21 & 26 @ DELTA offices



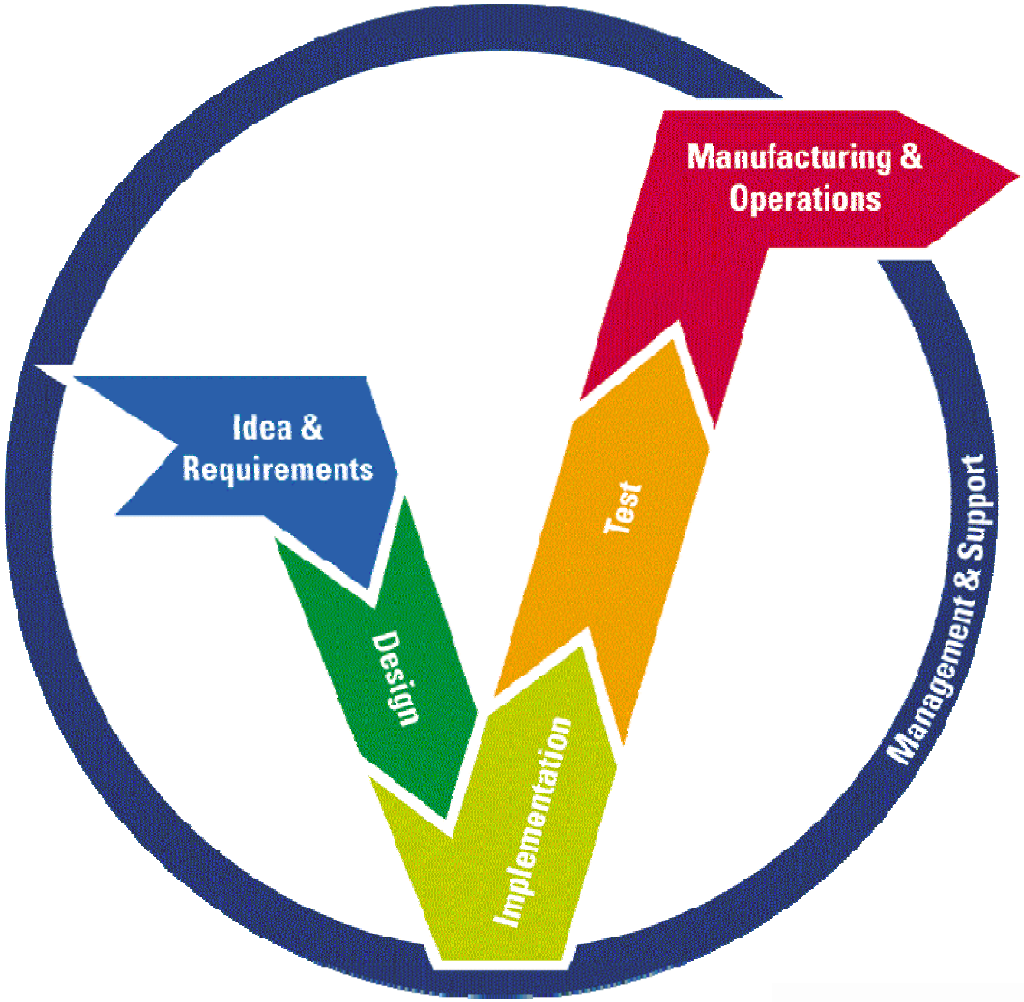
The big trade-off



Common technologies

Name	Frequency	Datarate	Tx power	Range	Max. nodes
Bluetooth 2.1, Class 1	2.4 GHz	1-3 Mbps	100 mW	100 m	7 slaves per master
ZigBee, 2.4 GHz	2.4 GHz	250 kbps	1 mW	10-100 m	4090 nodes
ZigBee, 868 MHz (EU)	868 MHz	20 kbps	1 mW	10-100 m	4090 nodes
Z-Wave	868 MHz	9.6/40 kbps	1 mW	30-100 m	232 nodes

When should you list your requirements?



Why are we doing this?

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