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From Passive to Active: Relay-Assisted Wireless Energy Transfer

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WiSeNet

About WiSe-Net Lab

Established in 2005, WiSe-Net lab researchers have been conducting cutting edge R&D that led into development of wireless sensors for lunar habitat monitoring (shape, impact, leak), launched rockets with wireless sensors on board, and developed a payload for ISS.

umaine.edu/wisenetlab/

Passive vs Active Wireless Sensing

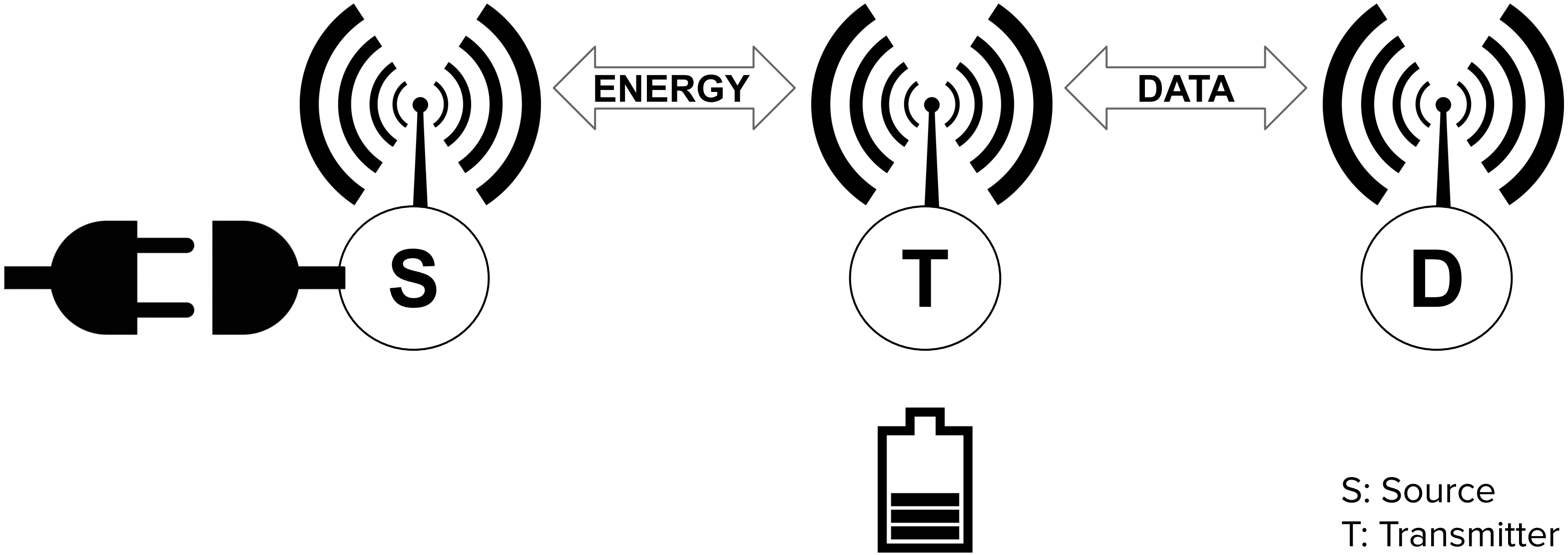
Passive Sensing

1. No batteries needed
2. Small form factor
3. Low maintenance
4. Low weight and cost
5. Flexible location change
6. No processing power
7. Short range

Active Sensing

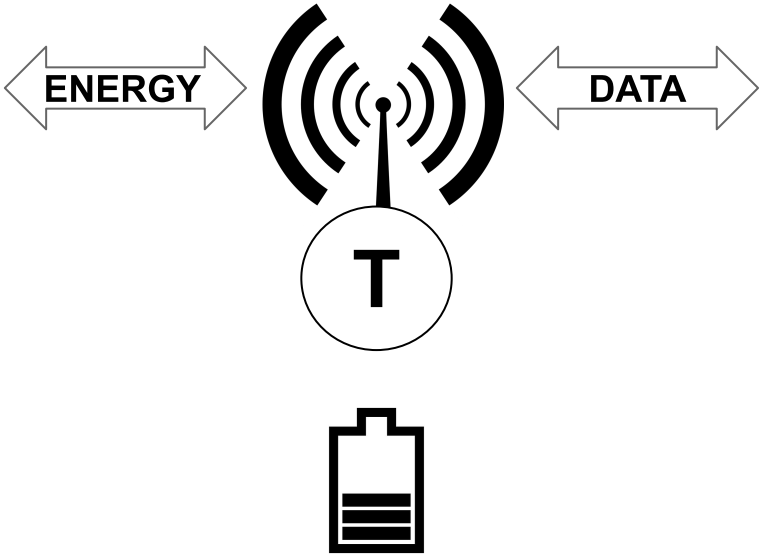
1. Batteries needed
2. May not be small
3. Requires maintenance
4. Higher weight and cost
5. Flexible location change
6. High processing power
7. Longer range

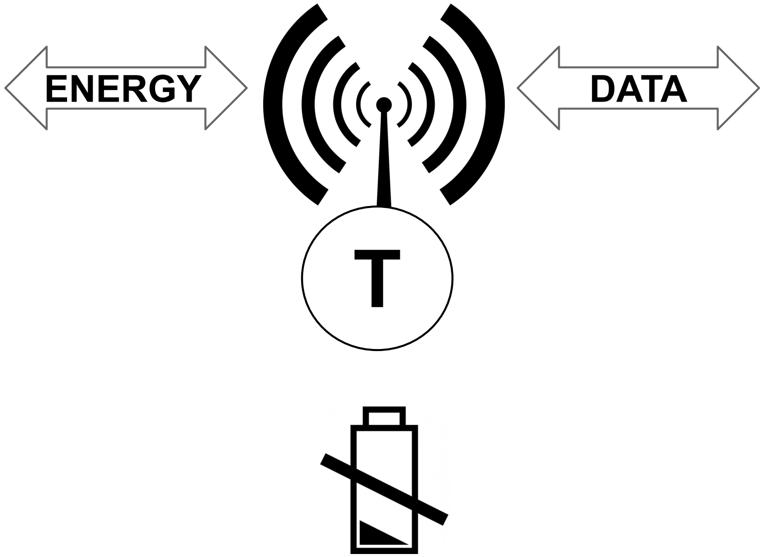
Wireless Energy Transfer (WET)



S: Source
T: Transmitter
D: Destination

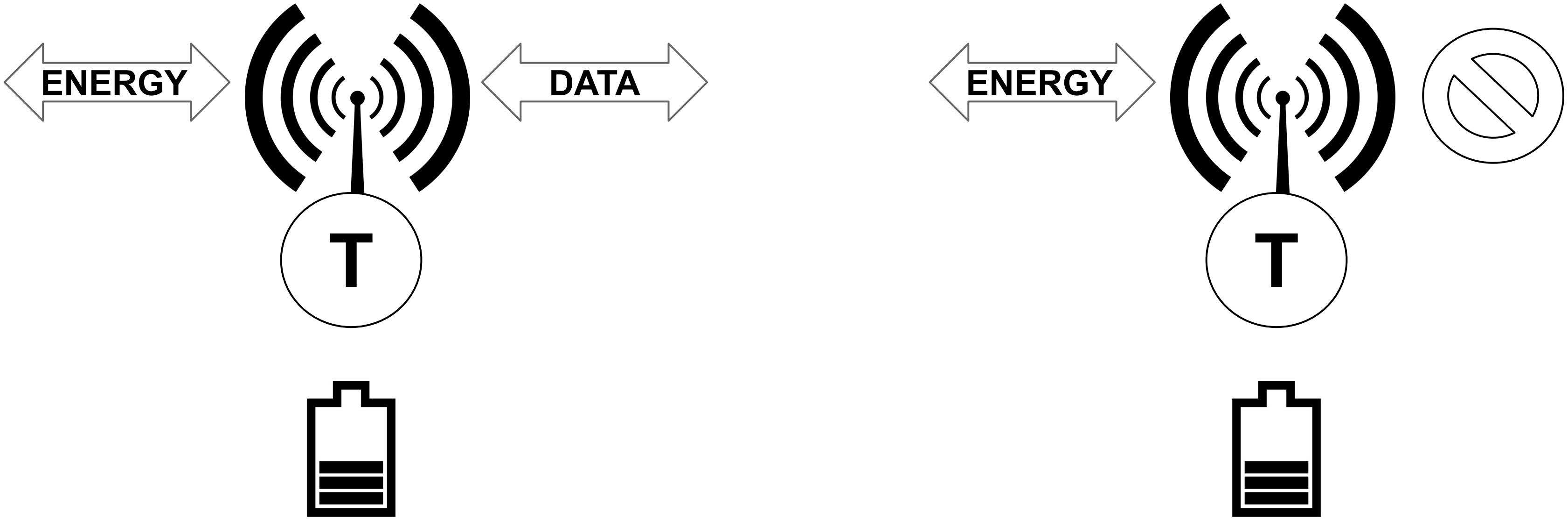
Transmission Scheduling (Battery)



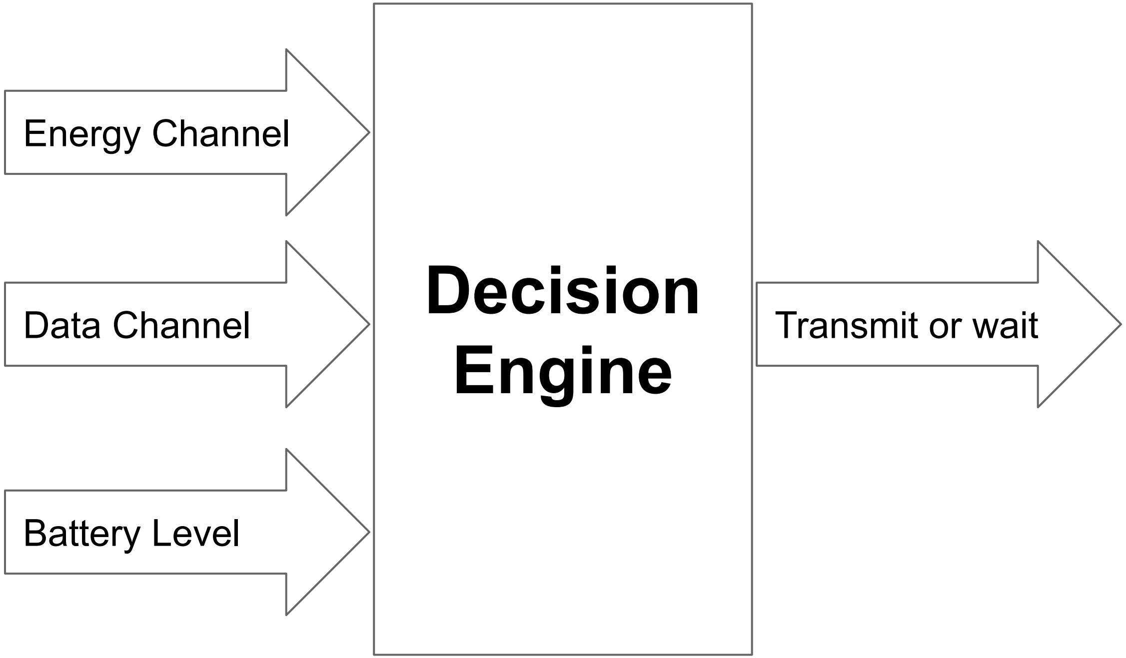


Transmission Scheduling (Energy)

Transmission Scheduling (Data)



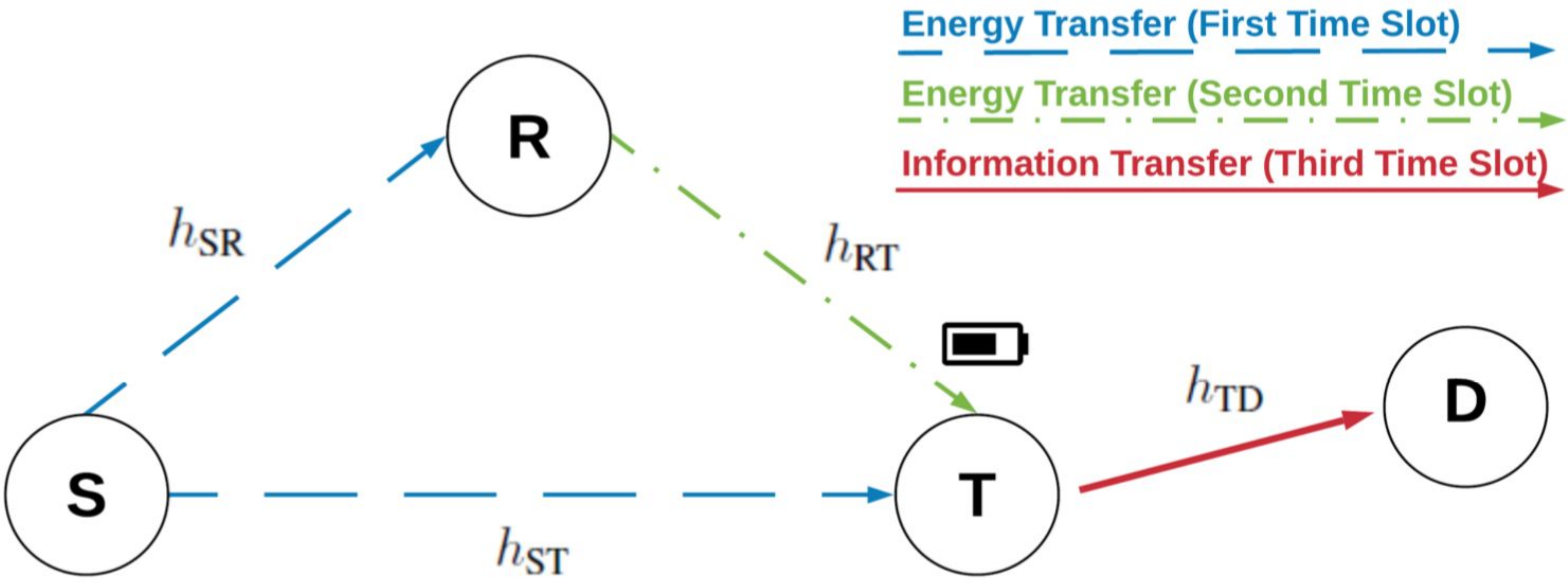
Transmission Scheduling



Parameters to consider?

Objective to maximize?

Relay-Assisted WET



Dual Energy-Data Channel Model

Energy \ Data	AWGN	Rayleigh	Rician
AWGN: **Additive White Gaussian Noise**	Static networks	Static charging for a mobile sensor	Static charging for a mobile sensor with LOS
Rayleigh: **Statistical fading channel w/o LOS**	Mobile charging for a static sensor	Mobile sensor	Mobile charging for a mobile sensor with LOS
Rician: **Statistical fading channel with LOS**	Mobile charging with LOS for a static sensor	Mobile charging with LOS for a mobile sensor	Mobile sensor with LOS

LOS: Line of Sight

Channel Models

AWGN:
Additive White Gaussian Noise

$$f(x) = N(\mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(x-\mu)^2/2\sigma^2}$$

Rayleigh:
Statistical fading channel w/o LOS

$$g(y, \sigma^2) = \frac{y}{\sigma^2} e^{-\frac{y}{2\sigma^2}}$$

Rician:
Statistical fading channel with LOS

$$h(z, \sigma^2) = \frac{z}{\sigma^2} e^{-(z^2+v^2)/2\sigma^2} I_0(\frac{zv}{\sigma^2})$$

Outage Probability at Relay

Received energy at the relay node over the first time slot

Required energy for the relay to operate

$$P_R^E = \Pr(\text{outage at relay}) = \Pr(X_R^{(1)} \leq \theta_R)$$

$$= \int_{-\infty}^{\theta_R} N(\mu_{SR}, \sigma_{SR}^2)dx = \frac{1}{2}\left[1 + erf\left(\frac{\theta_R - \mu_{SR}}{\sigma_{SR}\sqrt{2}}\right)\right]$$

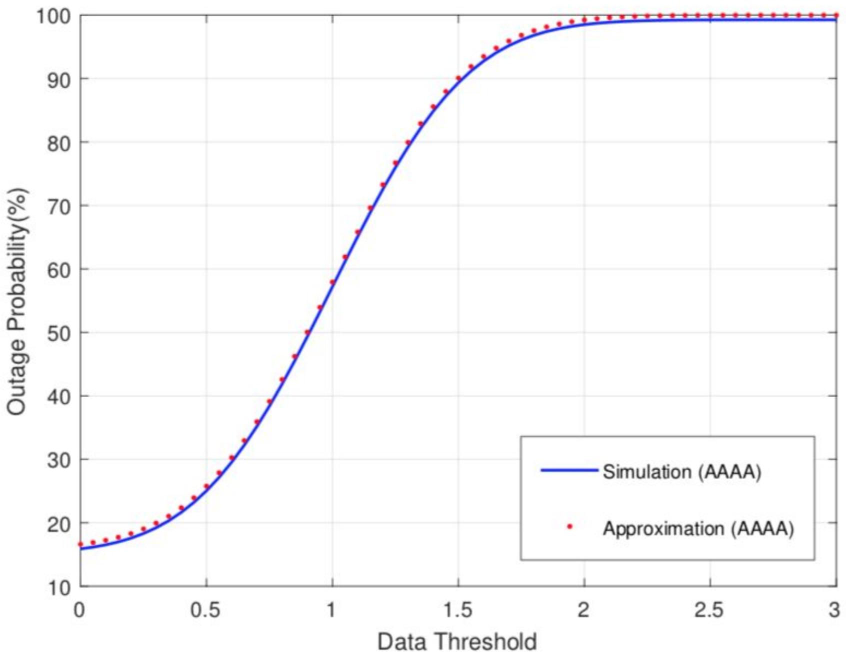
Outage Probability at Transmitter

$$\mathrm{P}_{\mathrm{T}}^{\mathrm{E}} \overset{\triangle}{=} \Pr(\text{energy outage with relay})$$
$$= \int_{-\infty}^{\theta_{\mathrm{T}}} f_{X_{\mathrm{T}}^{(1),(2)}}(x)\,dx$$

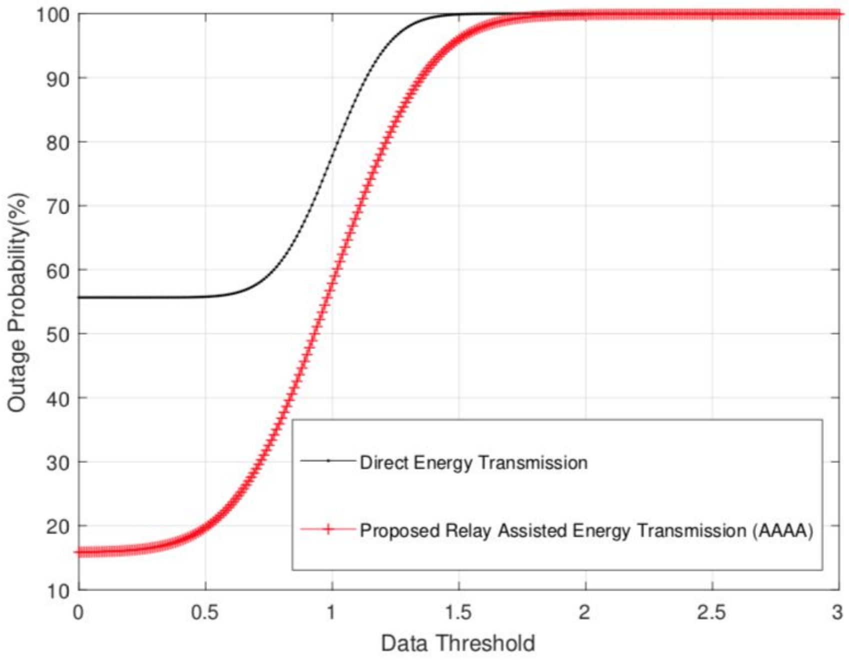
$$\mathrm{P}_{\mathrm{T}}^{\mathrm{D}} \overset{\triangle}{=} \Pr(\text{data outage with relay})$$
$$= \int_{-\infty}^{\theta_{\mathrm{Data}}} \frac{x}{\sigma_{\mathrm{TD}}^{2}} e^{-\frac{x}{2\sigma_{\mathrm{TD}}^{2}}}\,dx$$

$$\overline{\mathrm{P}_{\mathrm{T}}^{\mathrm{E}}} = \Pr(\text{energy outage w/o relay})$$
$$= \int_{-\infty}^{\theta_{\mathrm{T}}} h(x, \sigma_{\mathrm{ST}}^{2})\,dx$$

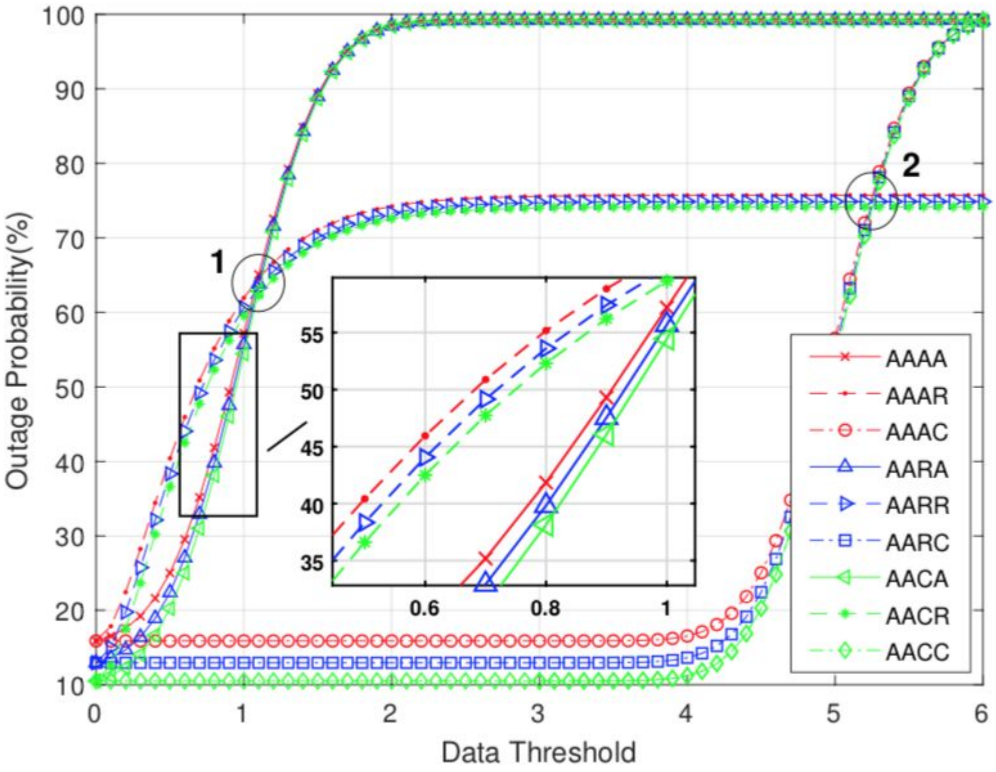
Theory vs Simulations



Relay vs Direct



All Scenarios: Static/mobile



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