QuarkOS: Pushing the operating limits of micro-powered sensors

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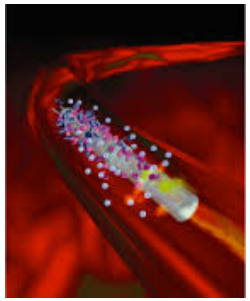
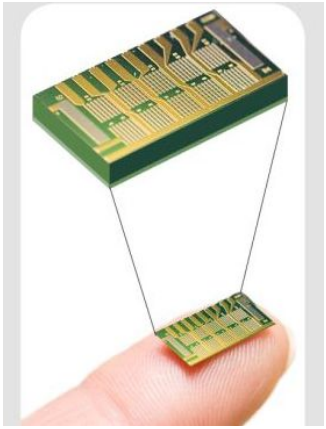
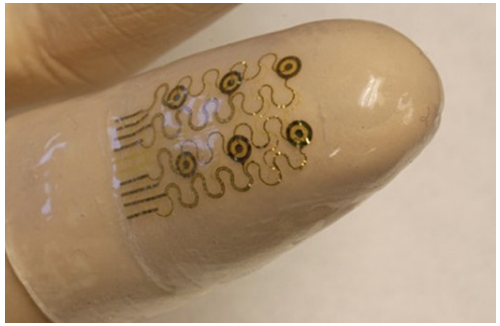
Frontier of wireless sensing



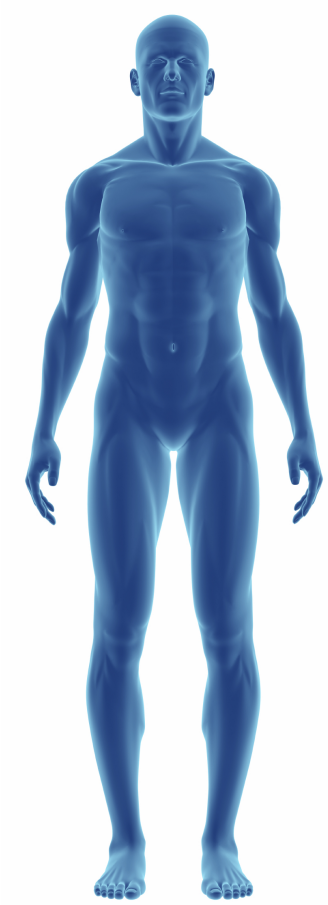
Glucose sensor in bloodstream

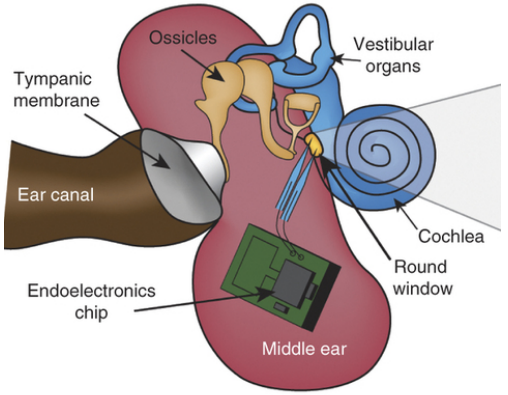


Long-term drug delivery



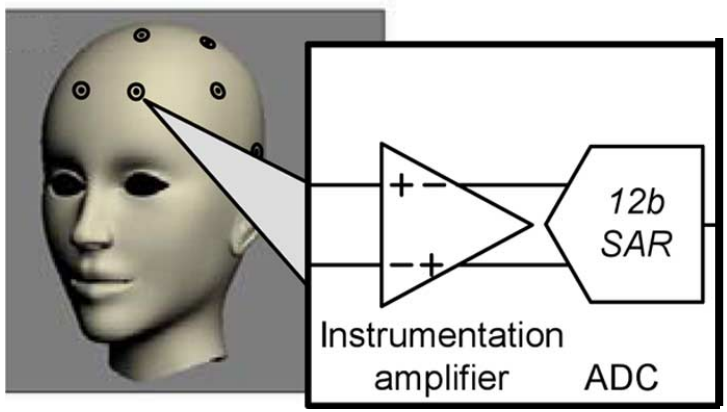
Epidermal electronics





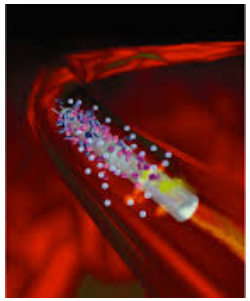
In-ear molecular sensor

Vital signs bandaid



EEG acquisition

How to power these devices?



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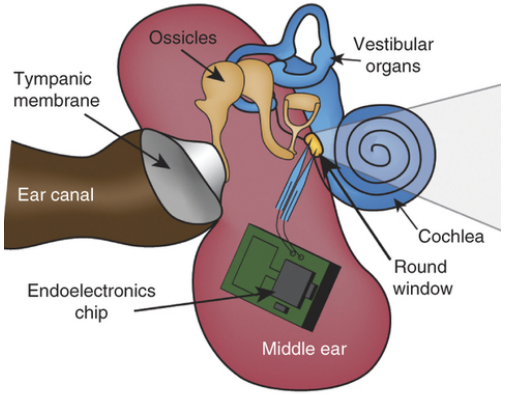

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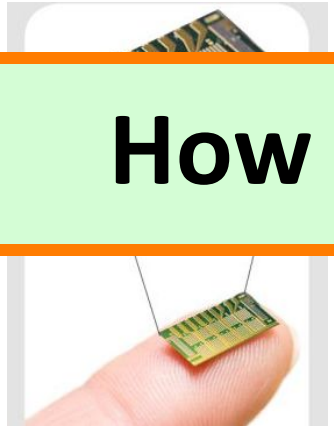

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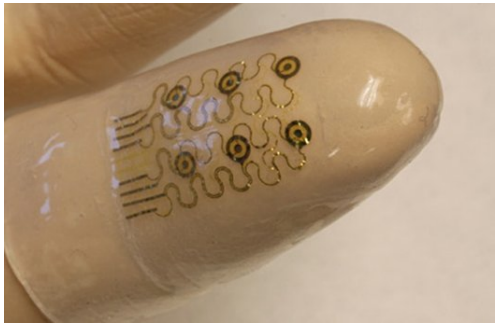

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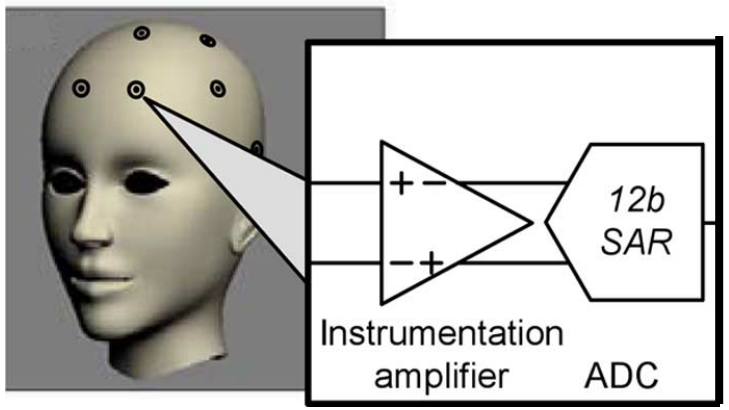
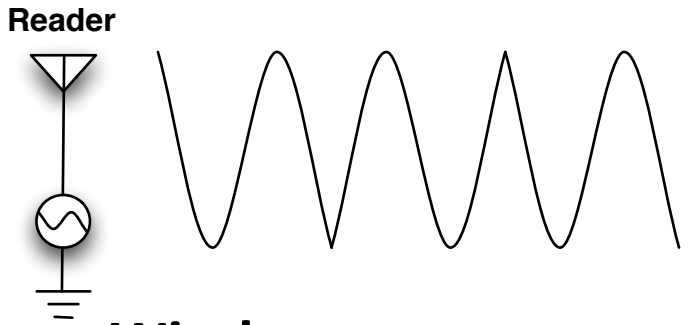


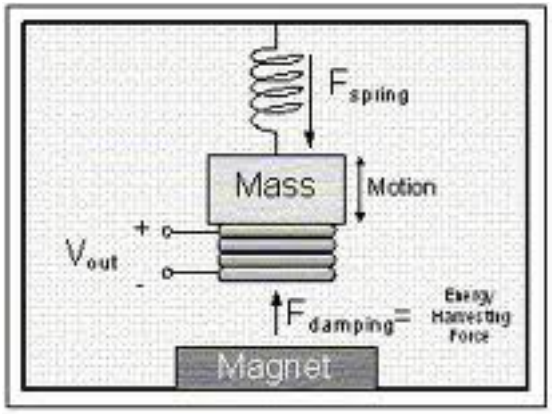
EEG acquisition

Energy harvesting sources

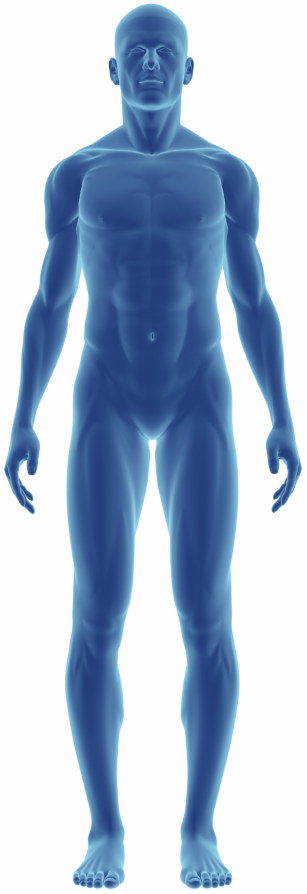
Micro-solar cells

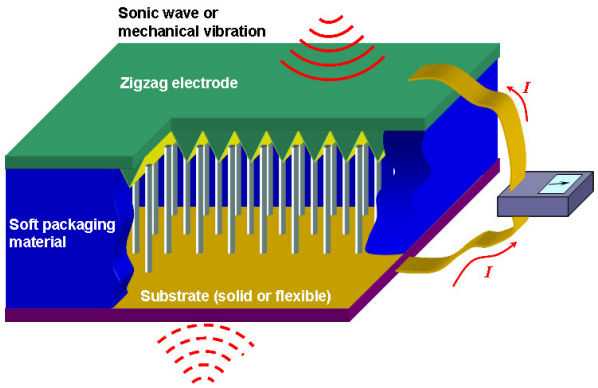


Wireless power

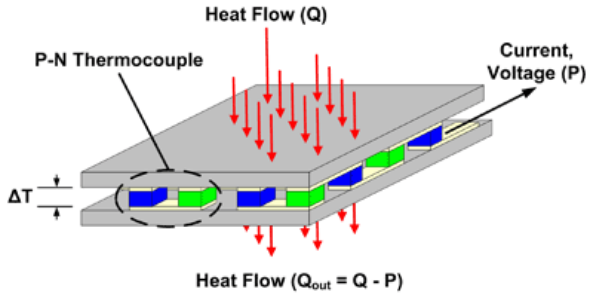


Vibration energy harvester

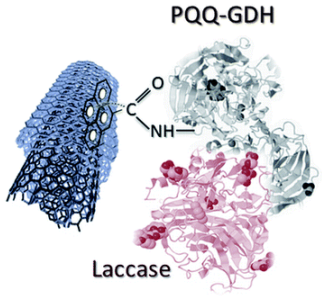




Nanogenerator



Thermal gradient



Biofuel cells

Power regime

	buffer size (Ah)	power (mW)
mote-class sensor	0.2	5.4
mm-cube sensor	0.6*10^-6	10*10^-6

micro-powered devices have 6 order of magnitude smaller buffer as well as harvested power

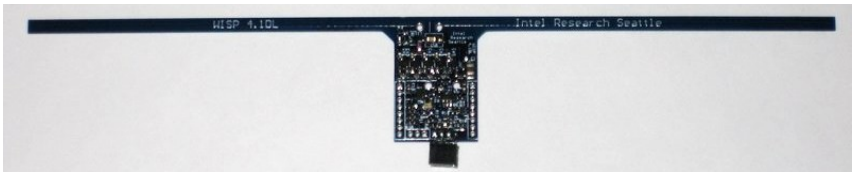
Existing OS for micro-powered sensors

When we scale down by so many orders of magnitude, assumptions made by existing sensor systems break down

TinyOS **Contiki** **Nano-RK**

Mote

Mementos **Dewdrop**



Intel/UW WISP

Natural light harvesting
Tiny capacitor buffer

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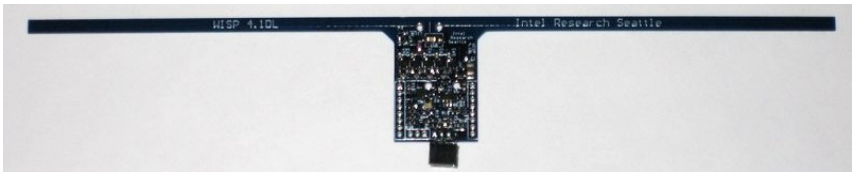


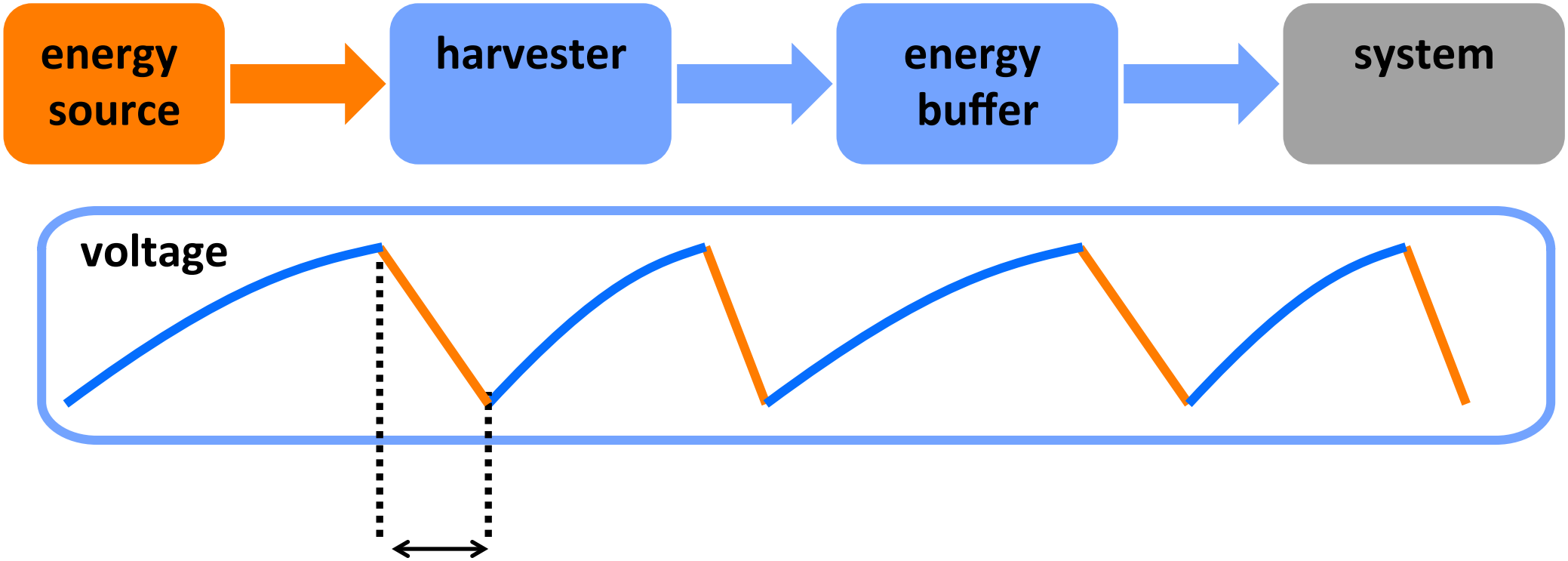
Intel/UW WISP

~~Natural light harvesting~~
~~Tiny capacitor buffer~~

Why is it so difficult to design systems that can scale down to micro-powered settings?

How micro-powered device work?

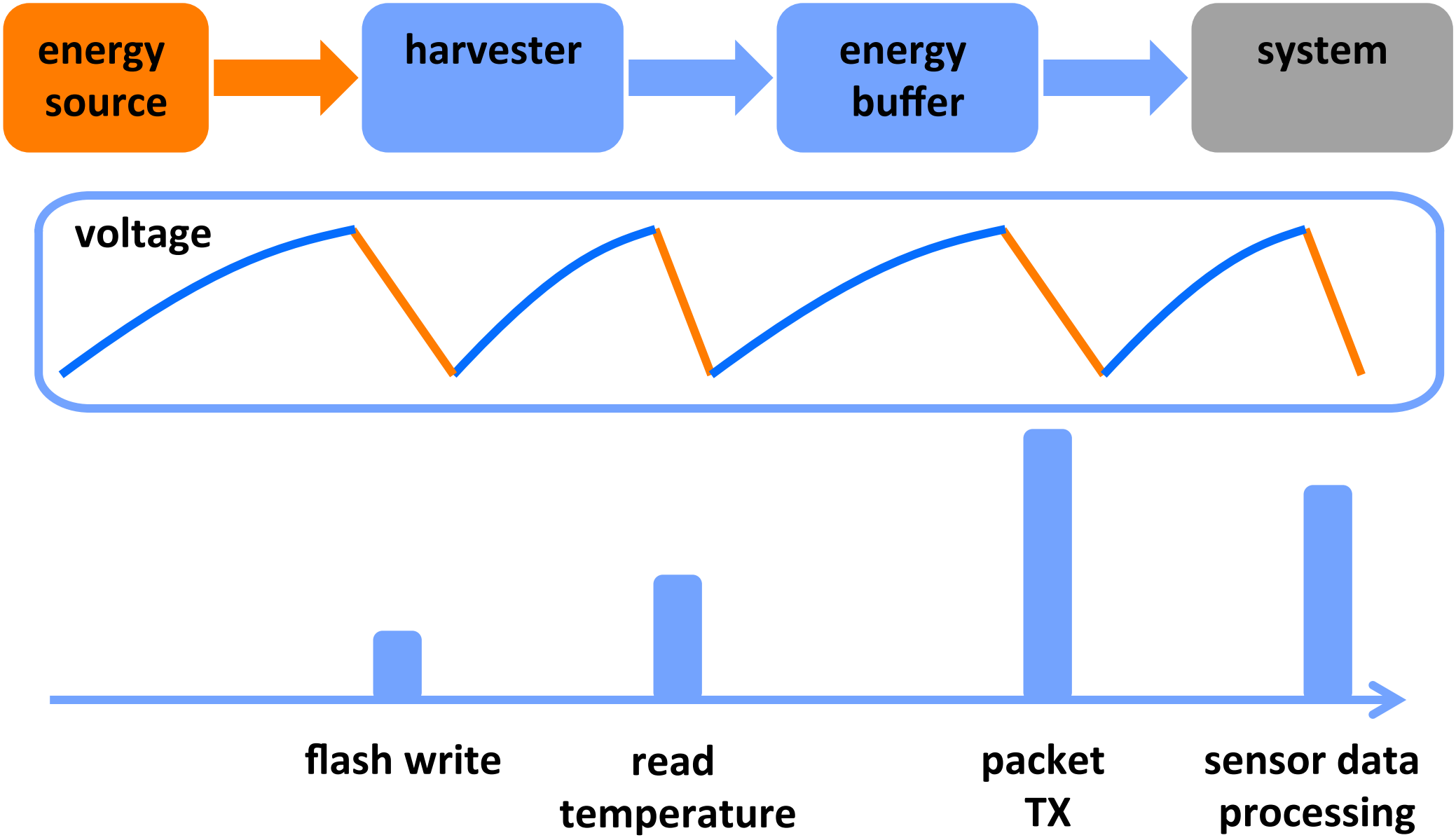
Energy harvesting system



available energy is miniscule

How micro-powered device work?

Energy harvesting system



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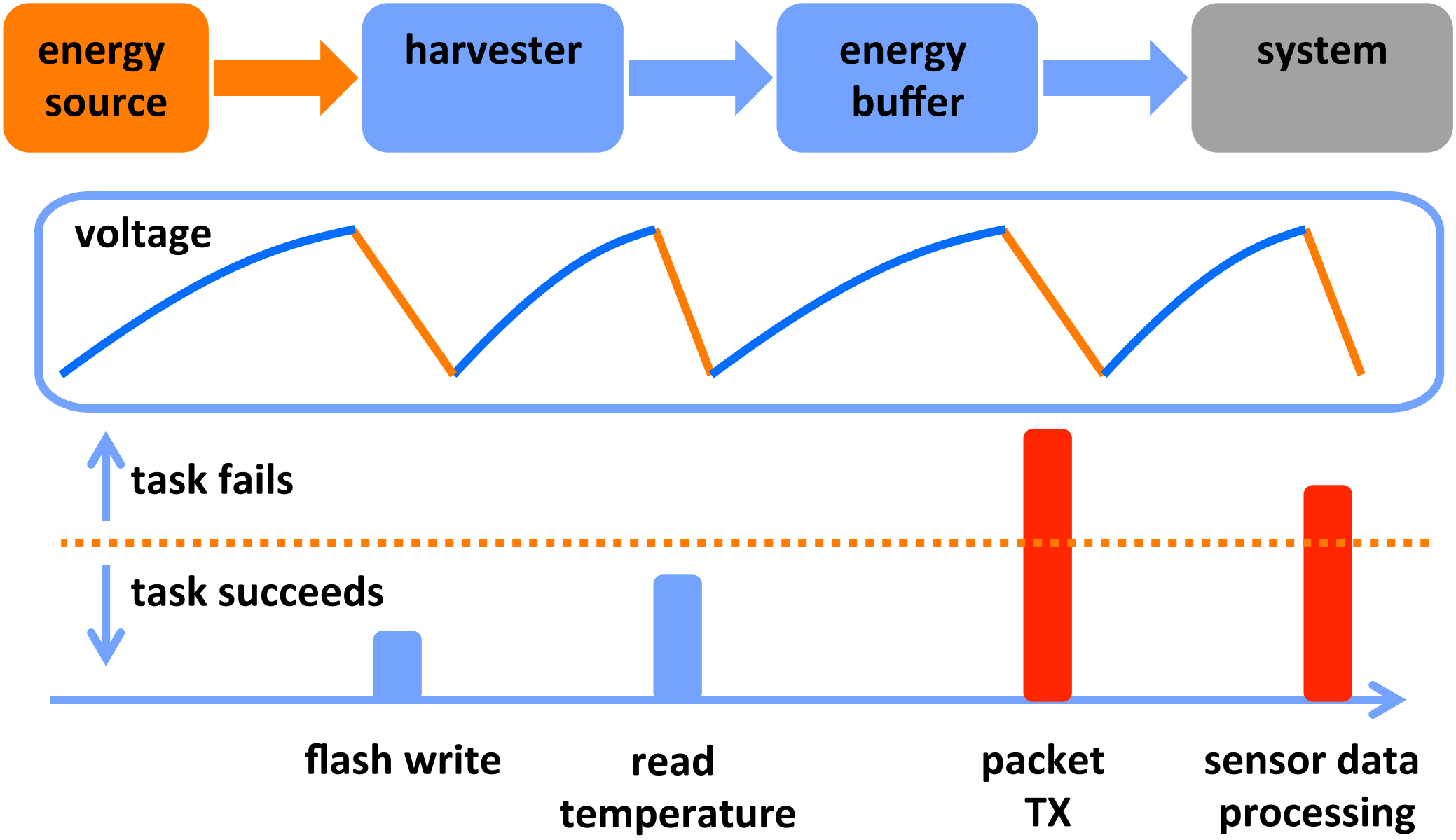

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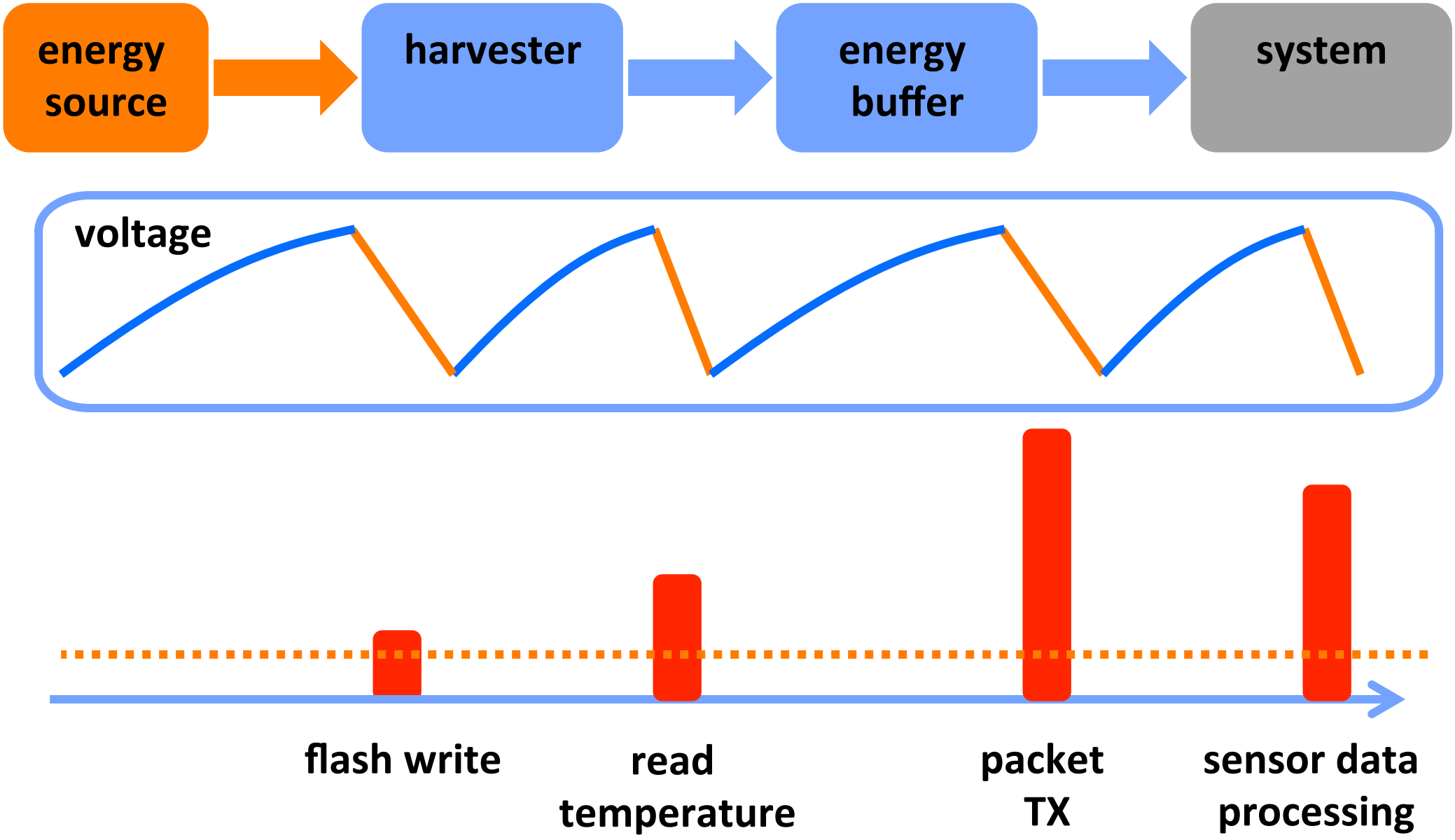

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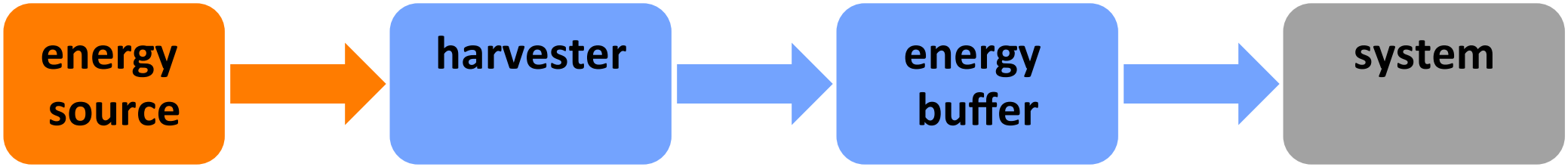
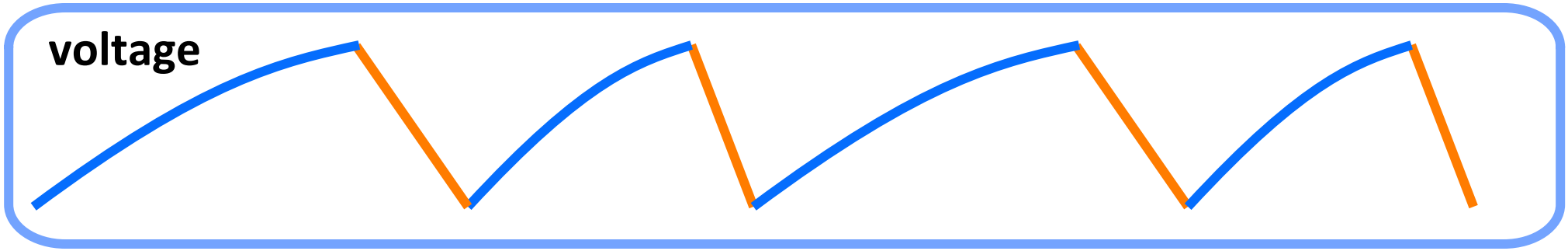




Bottleneck:
Task energy budget > Buffered energy

flash write

read temperature

packet TX

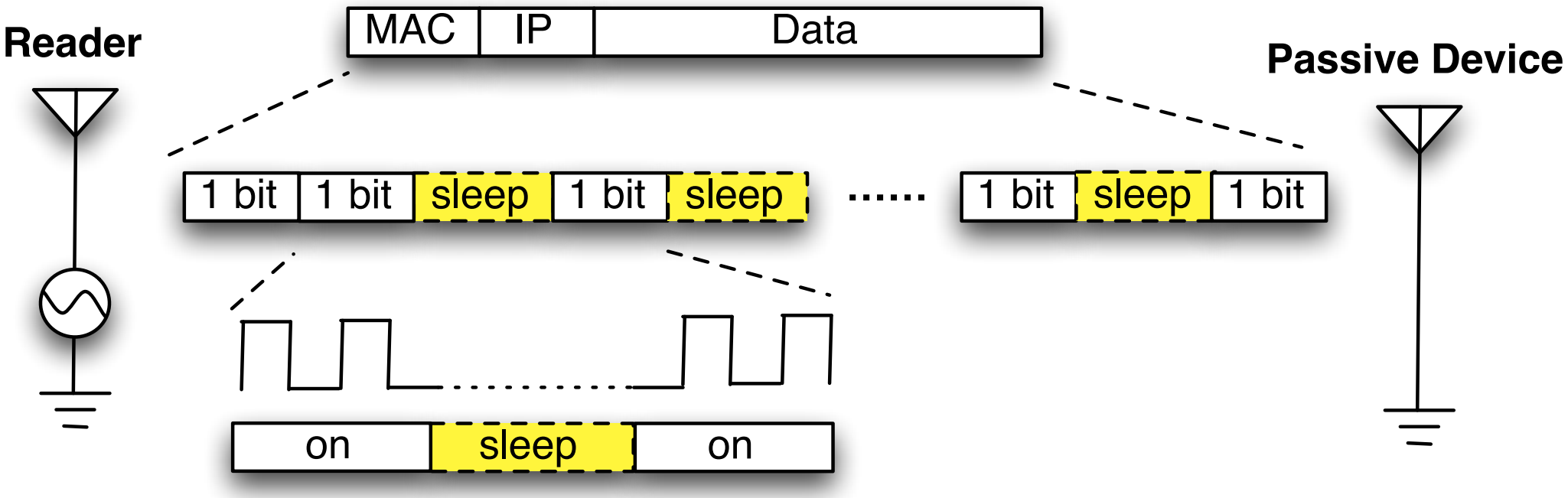
sensor data processing

QuarkOS

QuarkOS is designed to fragment data transfer, sensing, processing, and storage into the finest granularity possible.

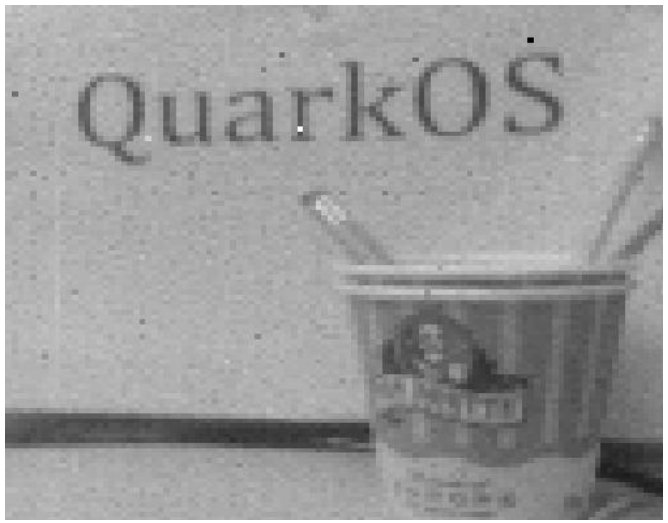
QuarkOS: Bit-by-bit communication

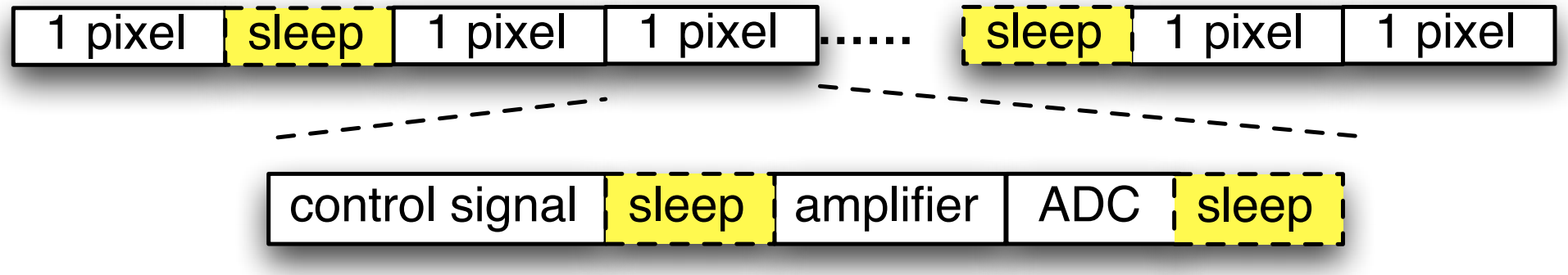
We show that a bit-by-bit communication stack can operate at 3x lower harvesting regimes



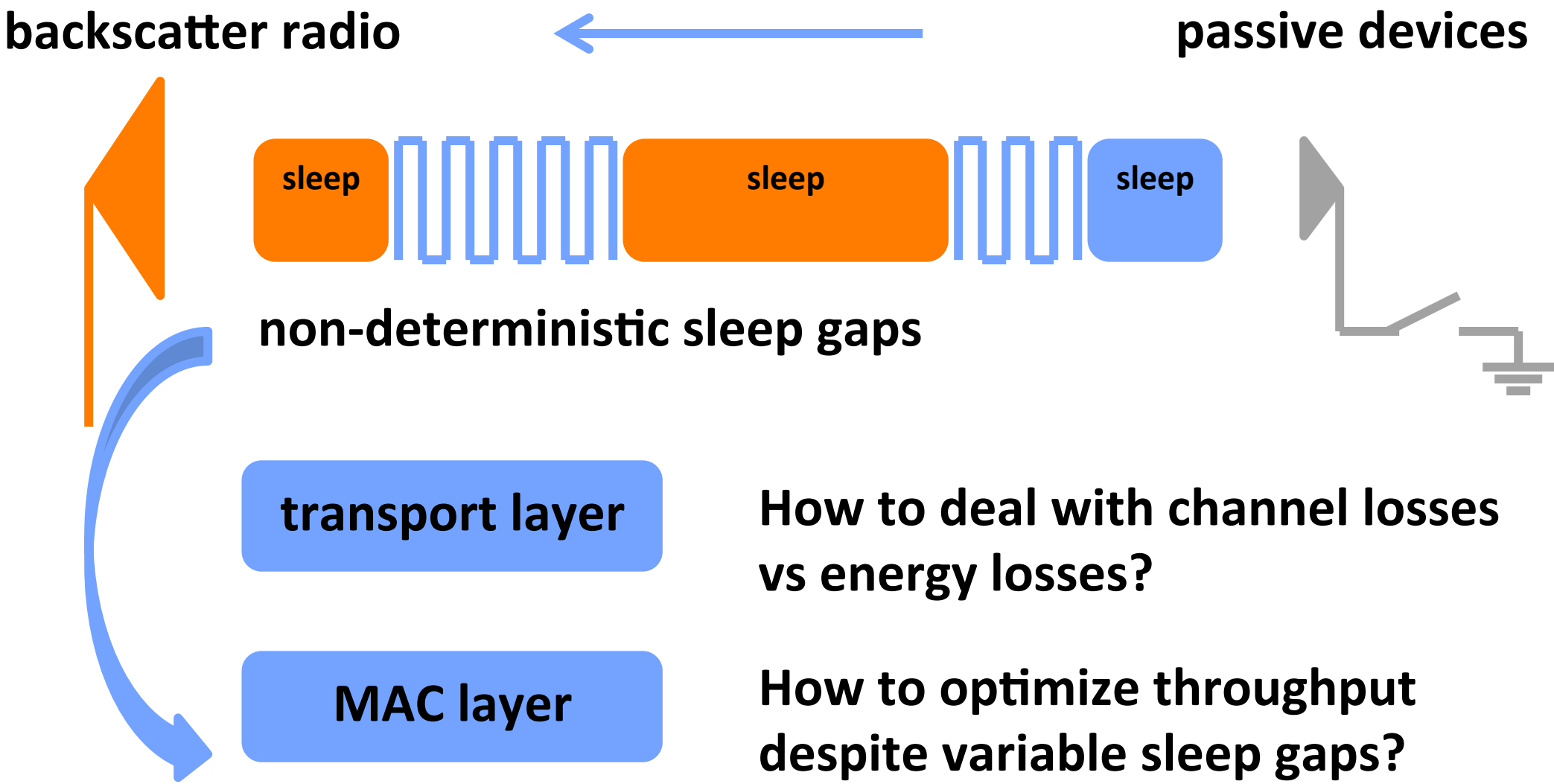
QuarkOS: Pixel-by-pixel image sensing

We show that pixel-by-pixel image sensing can enable operation with a small solar panel under natural indoor light.





Challenges: Network stack design

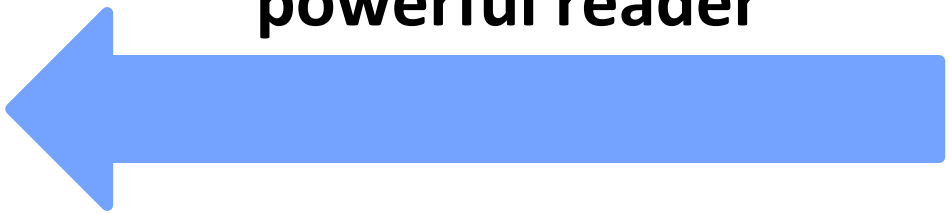


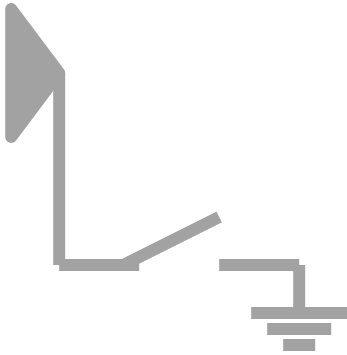
Network stack design challenges

backscatter radio

passive devices

offload complexity to powerful reader





transport layer	How to deal with channel losses vs energy losses?
MAC layer	How to optimize throughput despite variable sleep gaps?
physical layer	How to decode variable sized fragments?

Challenges: Sensing stack

non-deterministic sleep gaps

Application	What is the impact on application fidelity?
Image processing	How to deal with motion blur due to variable sleep gaps?
Physical layer	How to reduce the power consumption of single pixel sensing?

Conclusion

- As wireless sensor devices scale down, so too should the software system running on these devices.
- Fragment every piece of the system to minimize the energy required for any fragment.
- We demonstrate the power of QuarkOS by fragmenting two components of an OS: passive communication and image sensing.

Thank you!