Technische Universität Braunschweig

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A Node's Life – Increasing WSN Lifetime by Dynamic Voltage Scaling

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DVS for WSNs

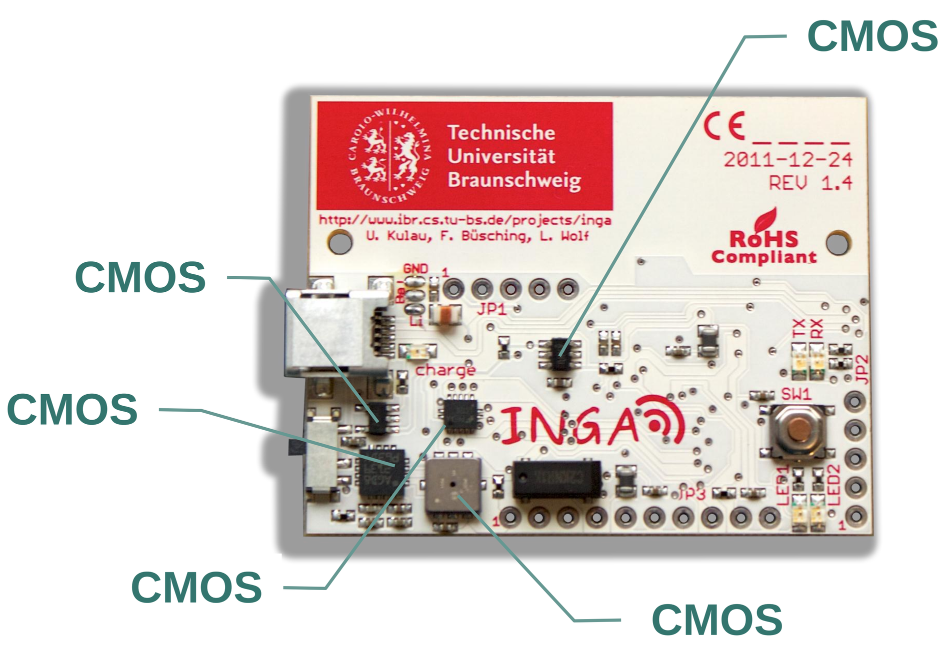
In mobile applications, like wireless sensor networks, it is often inevitable to use a location-independent source of energy. Wherever the batteries capacity or inefficient energy harvesting limits the lifetime, other solutions have to be implemented to increase the energy efficiency.

Beside the common Dynamic Power Management (DPM) with its several energy-saving sleep states, other mechanisms exist.

For example, Dynamic Voltage Scaling (DVS) is a well known technique with the ability to adapt the voltage level to the actual system load to save energy. While it has been used in many application areas, DVS has not been studied sufficiently for wireless sensor nodes.

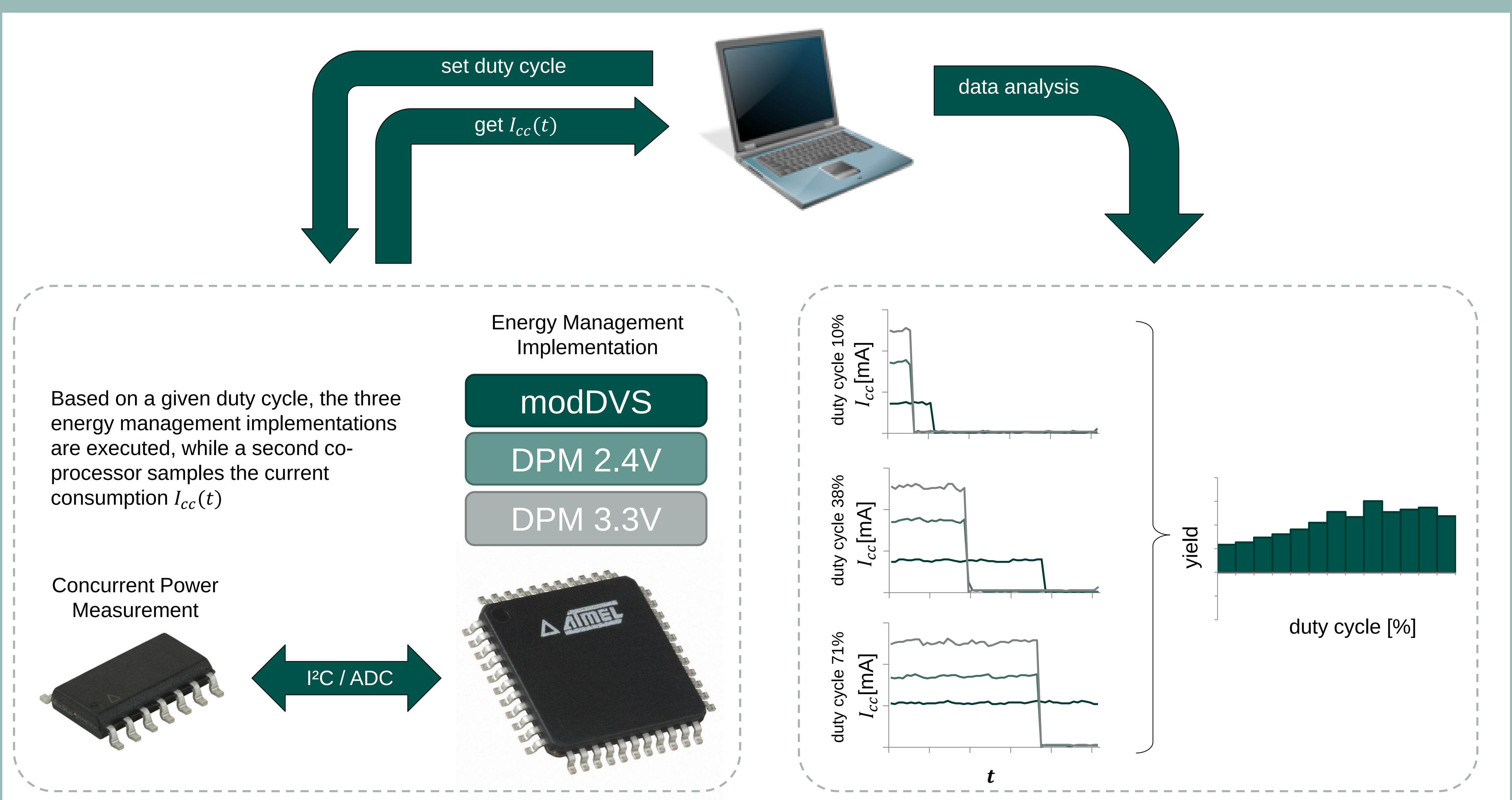
Background

Taking a closer look on the typical hardware architecture of wireless sensor nodes, or other embedded ULP (Ultra Low Power) micro controller systems, we see that most of the used integrated circuits are realized in CMOS technology.



$$P_{dyn} = C_L \cdot f_{cpu} \cdot V^2$$

The advantage of this technology is its theoretical non existing power consumption during static operation. An electrical current flow only occurs whenever the internal state of a CMOS gate is changed, so that the dynamic power consumption (P_{dyn}) dominates the total with an percentage of $\approx 75\%$. On the other hand the dynamic power consumption has a linear dependency on the clock rate (f_{cpu}) and a quadratic dependency on the voltage level (V). The parasitic capacity C_L depends on the quality of the manufacturing process



Demonstration

To show the benefit of an active voltage scaling module, we demonstrate a live measurement of three different energy management strategies.

While DPM3.3V operates with an usual system voltage level of 3.3V, DPM2.4V adapts to $V(f_{cpu})$ (here $2.4V$). modDVS is implemented as described below.

The live measurement is done by a second co-processor, which offers the data of one duty cycle.

Furthermore, we present the prototype implementation of a DVS capable wireless sensor node.

modDVS

With a model function $I_{cc}(f_{cpu}, V(f_{cpu}))$ it is possible to estimate the yield of a variable supply voltage compared to a fixed one. The yield is a factor of how much the current consumption can be reduced, when DVS is used instead of DPM. With DVS, although the processing will take more time due to the lower clock rate, a lower current consumption can be achieved because of the lower voltage

The calculation of the estimated yield shows, that a yield's peak exist whenever the absolute minimum supply voltage level V_{min} is reached. To improve the yield for workloads with $V(f_{cpu}) < V_{min}$, classical DPM can be used.

$$modDVS = \begin{cases} DVS & \forall\, V(f_{cpu}) \geq V_{min} \\ DPM & else \end{cases}$$