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COMPARSION OF ENERGY OPTIMIZATION METHODS FOR AUTOMOTIVE ETHERNET USING IDEALIZED ANALYTICAL MODELS

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AMAA 2015 July 08, 2015

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1 Introduction

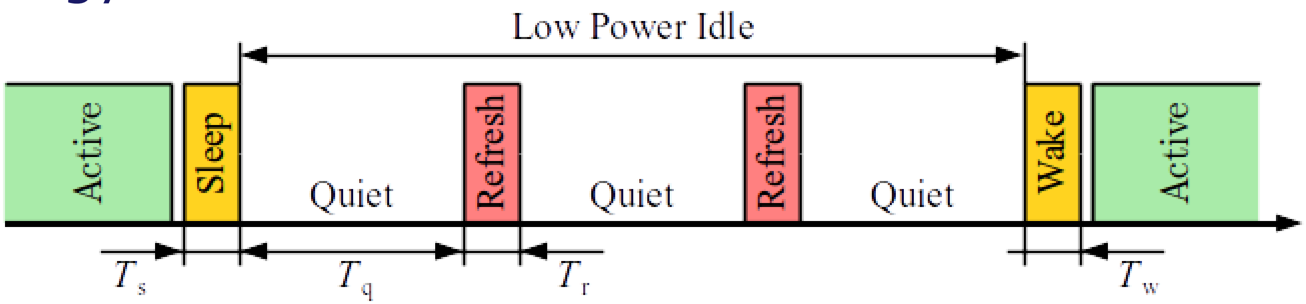
- Automotive Ethernet is an emerging technology
- Energy optimization is not yet the main focus
- In this paper a comparison of two approaches is presented
  - Using idealized traffic models
  - The presented considerations are based on paper by N. Balbierer

$$P_{\mathrm{PHY,EEE}}(u) = \begin{cases} \frac{P_{\mathrm{PHY,max}} - P_{\mathrm{PHY,LPI}}}{u_{\mathrm{th,EEE}}} u + P_{\mathrm{PHY,LPI}}; & u < u_{\mathrm{th}} \\ P_{\mathrm{PHY,max}}; & u \geq u_{\mathrm{th}} \end{cases}$$

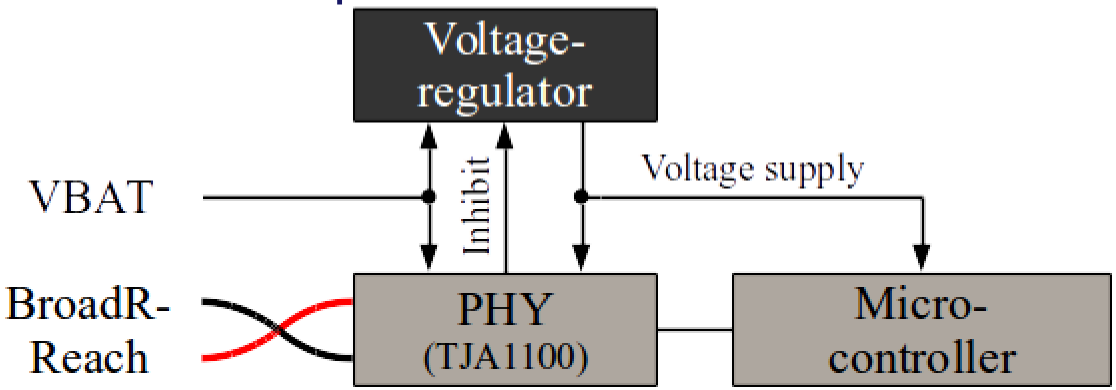
$$u_{\mathrm{th,EEE}} = \frac{s_{\mathrm{frame}}}{\left(T_{\mathrm{EEE}} + \frac{s_{\mathrm{frame}}}{r_{\mathrm{data}}}\right) r_{\mathrm{data}}}$$

2.1 Energy Optimization Methods

- Energy Efficient Ethernet



- Low Power Sleep



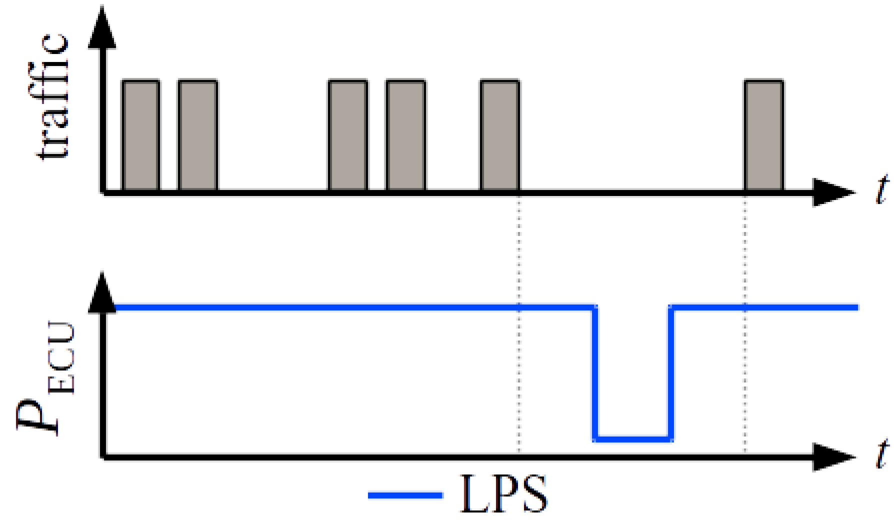
- Power over Ethernet (in particular Power over Data Line)
- Energy Detection Module
- Low Frequency Wakeup

2.2 Comparison of different concepts

Energy Efficient Ethernet

- only PHY is powered down
- low saving
- fast transition

Low Power Sleep



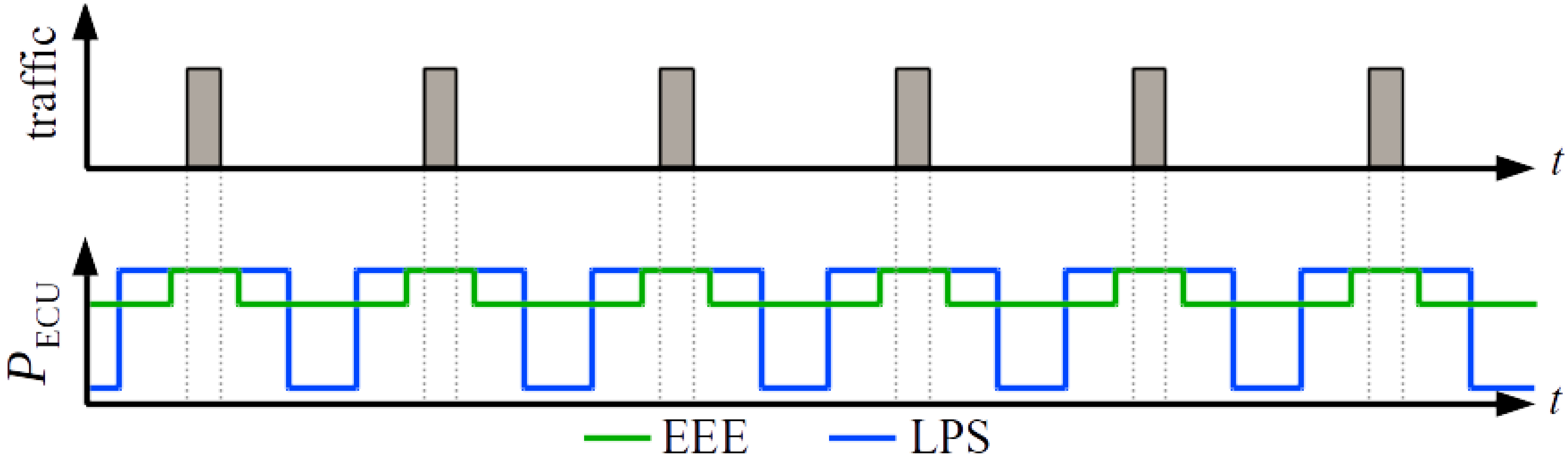
- whole ECU is powered down
- high saving
- slow transition

3 Idealized Analytical Models – Limitations

- Periodic Traffic
- Data rate: 100 Mbit/s
- Idealized timing
  - Constant transition times
  - Ideal timing of transitions
- Idealized power consumptions
  - Constant within a power mode
  - Ideal transitions
  - Not transient, e.g. no delays or overshooting
- Single point-to-point link

  → consecutive wakeups not considered

3.1 Model 1 – Periodic Frames



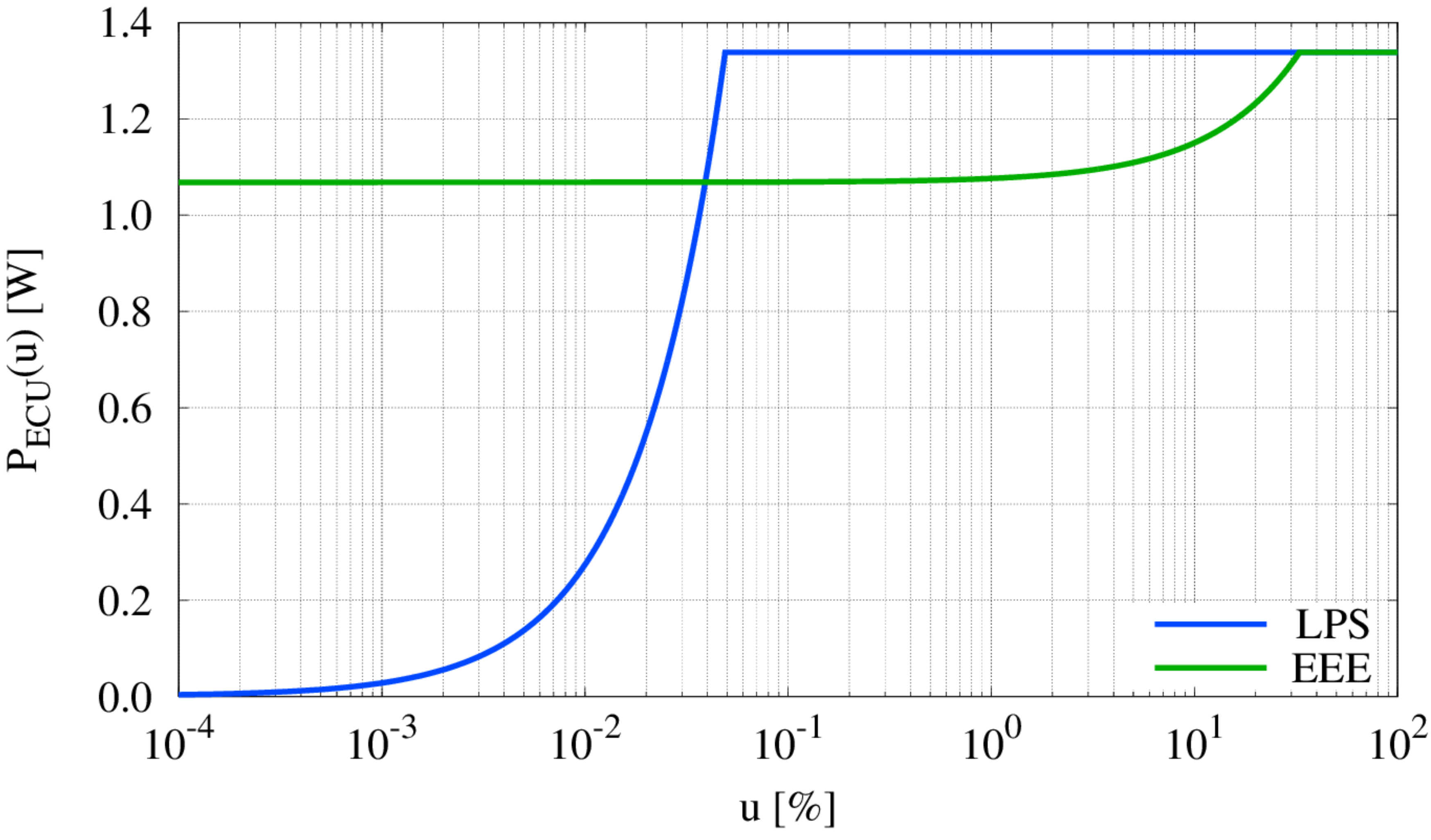
$$P_{ECU,EEE}(u) = \begin{cases} \frac{P_{PHY,max} - P_{PHY,EEE}}{u_{th,EEE}} u + (P_0 + P_{MAC} + P_{PHY,EEE}); & u < u_{th} \\ P_0 + P_{MAC} + P_{PHY,max}; & u \geq u_{th} \end{cases}$$

$$P_{ECU,LPS}(u) = \begin{cases} \frac{P_0 + P_{MAC} + P_{PHY,max} - P_{PHY,LPS}}{u_{th,LPS}} u + P_{PHY,LPS}; & u < u_{th} \\ P_0 + P_{MAC} + P_{PHY,max}; & u \geq u_{th} \end{cases}$$

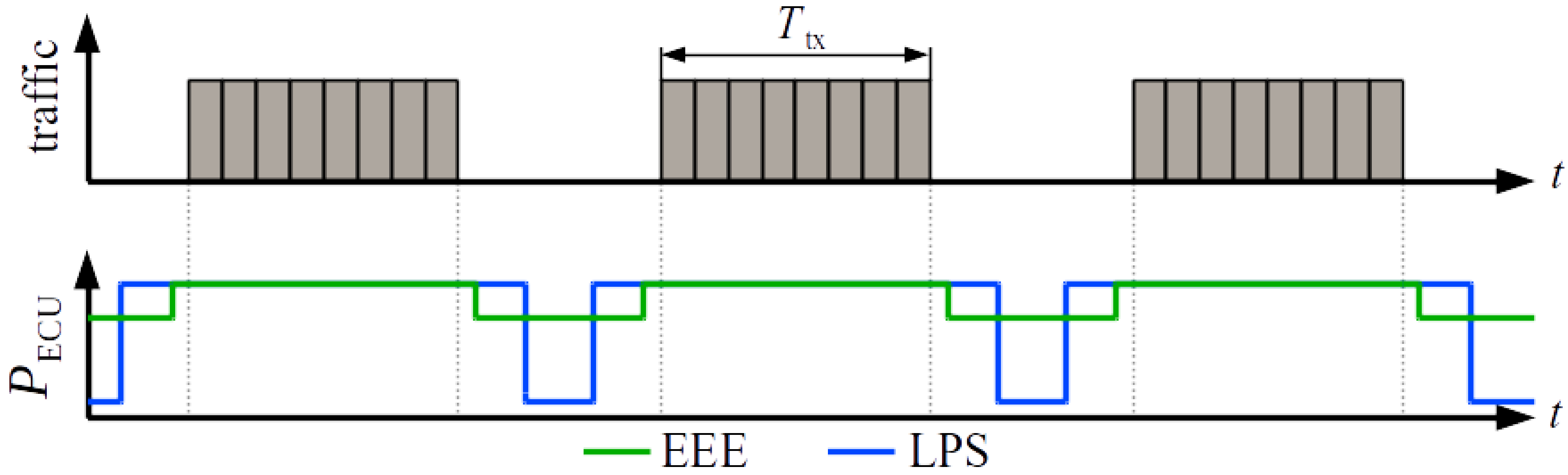
3.1 Assumed Parameters

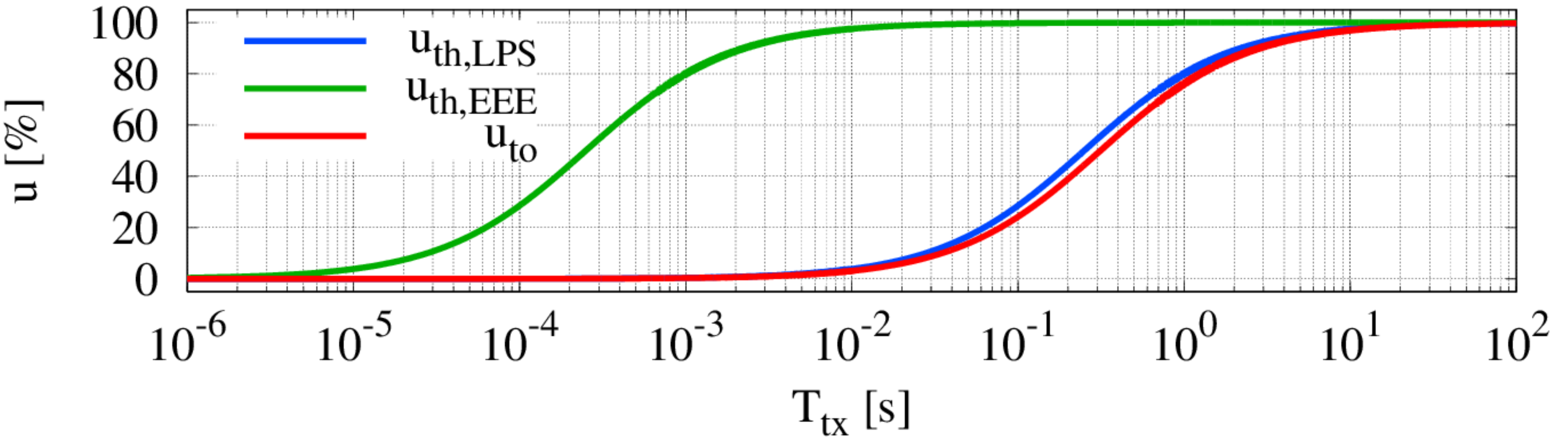
Description	Sign	Value
Power consumption of ECU (excl. NW omponents)	P_0	1000 mW
Power consumption of MAC	P_{MAC}	38 mW
Power consumption of PHY (normal mode)	$P_{\mathrm{PHY,max}}$	300 mW
Power consumption of PHY (LPI mode)	$P_{\mathrm{PHY,LPI}}$	30 mW
Power consumption of PHY (LPS mode)	$P_{\mathrm{PHY,LPS}}$	1 mW
Transition time for EEE	T_{EEE}	250 µs
Transition time for LPS	T_{LPS}	250 ms

3.1 Model 1 – Periodic Frames

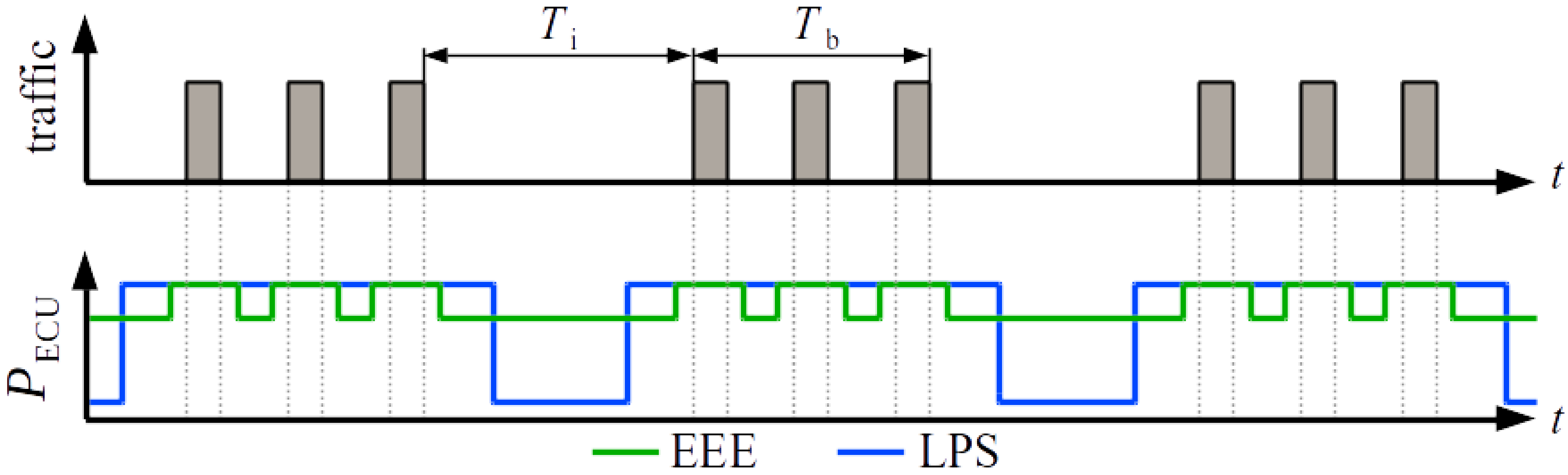


3.2 Model 2 – Periodic Blocks





3.3 Model 3 – Periodic Bursts



$$P_{ECU} = \frac{P_i T_i + P_b T_b}{T_i + T_b}$$

$$P_{ECU,x} = \frac{m_x u_b T_b + y_x (T_i' + T_b) + T_{tr,x} P_{max}}{T_i + T_b}$$

3.3 Model 3 – Periodic Bursts

$$P_{\mathrm{ECU,EEE}} = \frac{\frac{P_{\mathrm{PHY,max}} - P_{\mathrm{PHY,EEE}}}{u_{\mathrm{th,EEE}}} u_{\mathrm{b}} T_{\mathrm{b}} + P_{\mathrm{EEE}}(T_{\mathrm{i}}' + \mathrm{T_b}) + P_{\mathrm{ECU,max}} T_{\mathrm{EEE}}}{T_{\mathrm{i}} + \mathrm{T_b}}$$

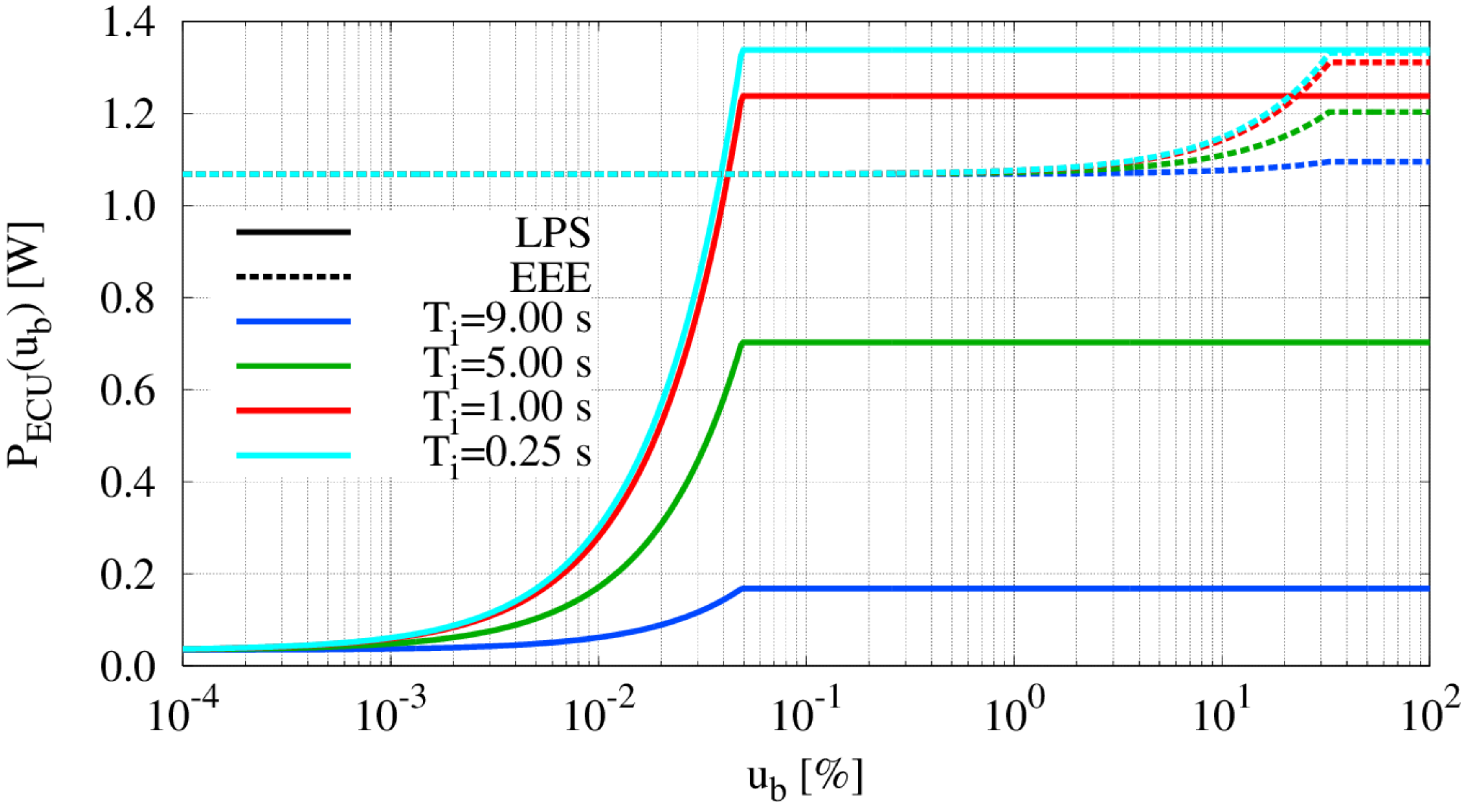
$$P_{\mathrm{ECU,LPS}} = \frac{\frac{P_{\mathrm{ECU,max}} - P_{\mathrm{PHY,LPS}}}{u_{\mathrm{th,LPS}}} u_{\mathrm{b}} T_{\mathrm{b}} + P_{\mathrm{PHY,LPS}}(T_{\mathrm{i}}' + \mathrm{T_b}) + P_{\mathrm{ECU,max}} T_{\mathrm{LPS}}}{T_{\mathrm{i}} + \mathrm{T_b}}$$

for $u_{\mathrm{b}} > u_{\mathrm{th}}$: $$P_{\mathrm{ECU,LPS}} = \frac{P_{\mathrm{max}}(T_{\mathrm{b}} + T_{\mathrm{LPS}}) + P_{\mathrm{PHY,LPS}} T_{\mathrm{i}}'}{T_{\mathrm{i}} + \mathrm{T_b}}$$

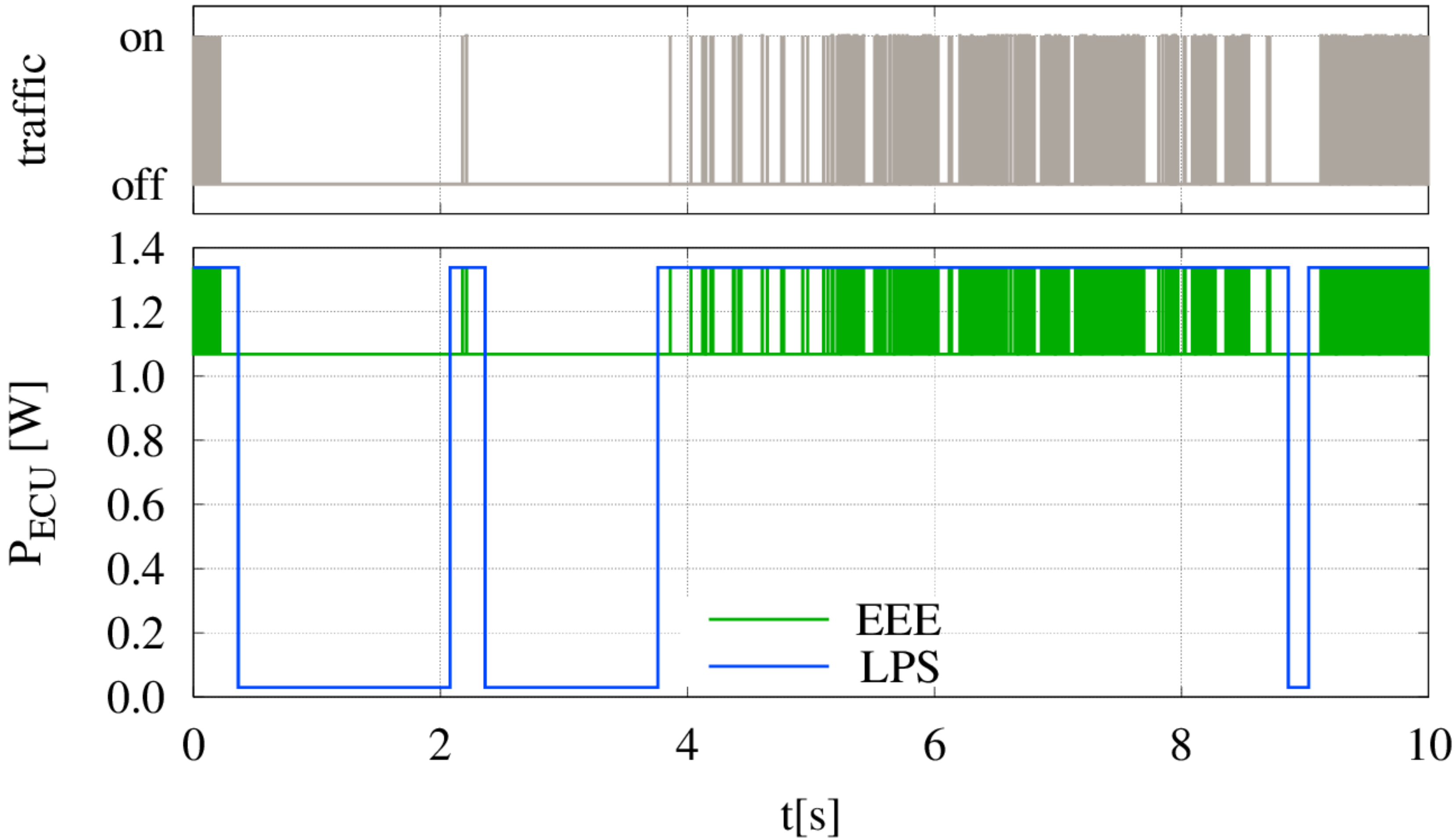
$$P_{\mathrm{ECU,EEE}} = \frac{P_{\mathrm{max}}(T_{\mathrm{b}} + T_{\mathrm{EEE}}) + P_{\mathrm{EEE}} T_{\mathrm{i}}'}{T_{\mathrm{i}} + \mathrm{T_b}}$$

3.3 Model 3 – Periodic Bursts

$$T = T_{\mathrm{i}} + T_{\mathrm{b}} = 10\ \mathrm{s} = \text{const.}$$



4 Script-Based Simulation



5 Conclusion

- Energy optimization methods can contribute considerable power savings
- Best suited method strongly depends on type of traffic
  - LPS best suited for ECUs that aren't required for prolonged periods
  - EEE suited for nodes that can't be powered down for prolonged periods (possibly inter-switch communication)
- Future work:
  - Consider more complex traffic models
  - Consider realistic transitions
  - Consider entire network
    - Multiple nodes
    - Consecutive wakeups