Energy-Efficient Sleep Mode Analysis and Optimization

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Agenda

1. IEEE 802.16m sleep mode
2. Energy efficiency
3. QoS in IEEE 802.16 technology
4. Optimization task
5. System models
6. Conclusion

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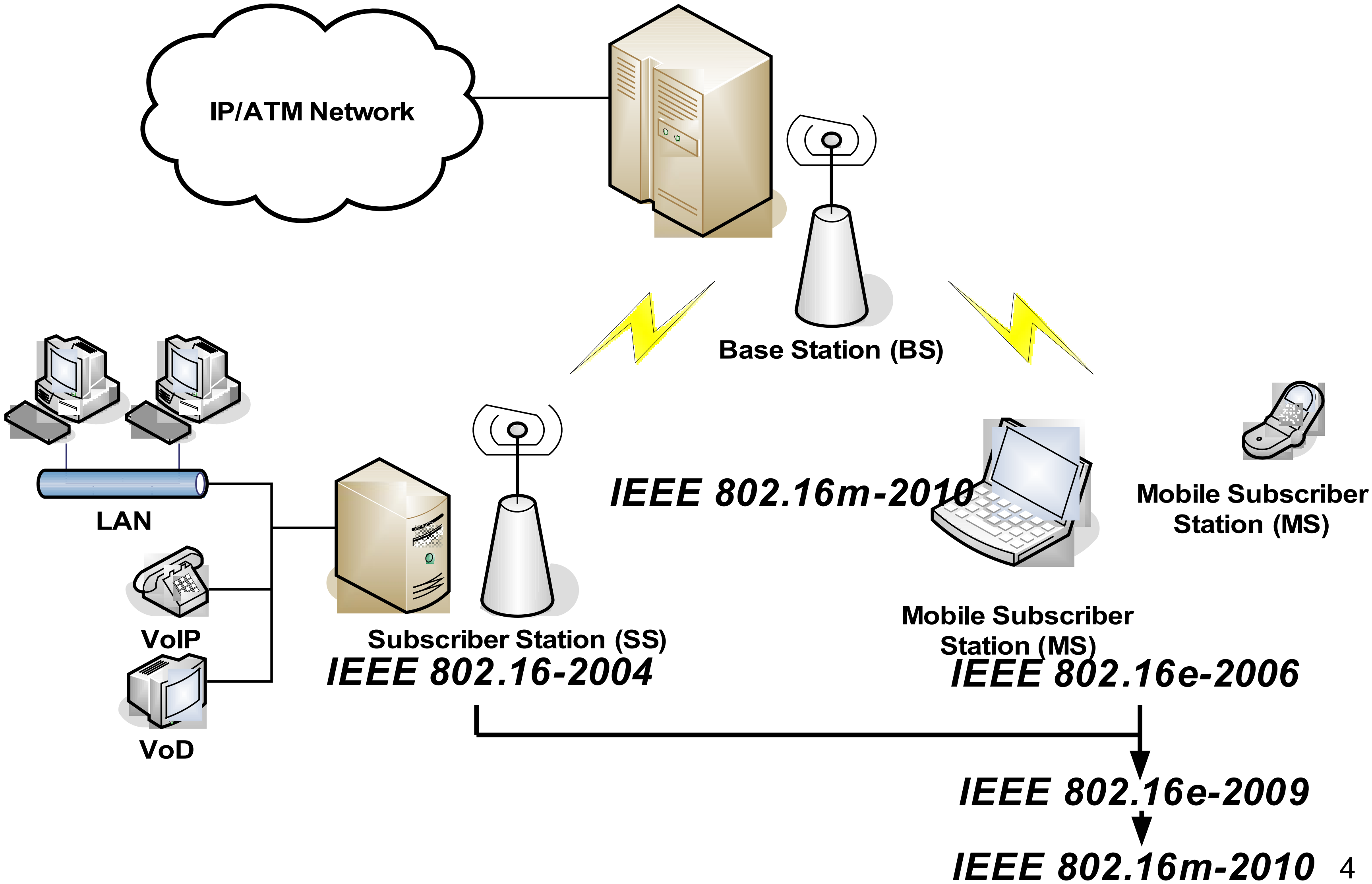
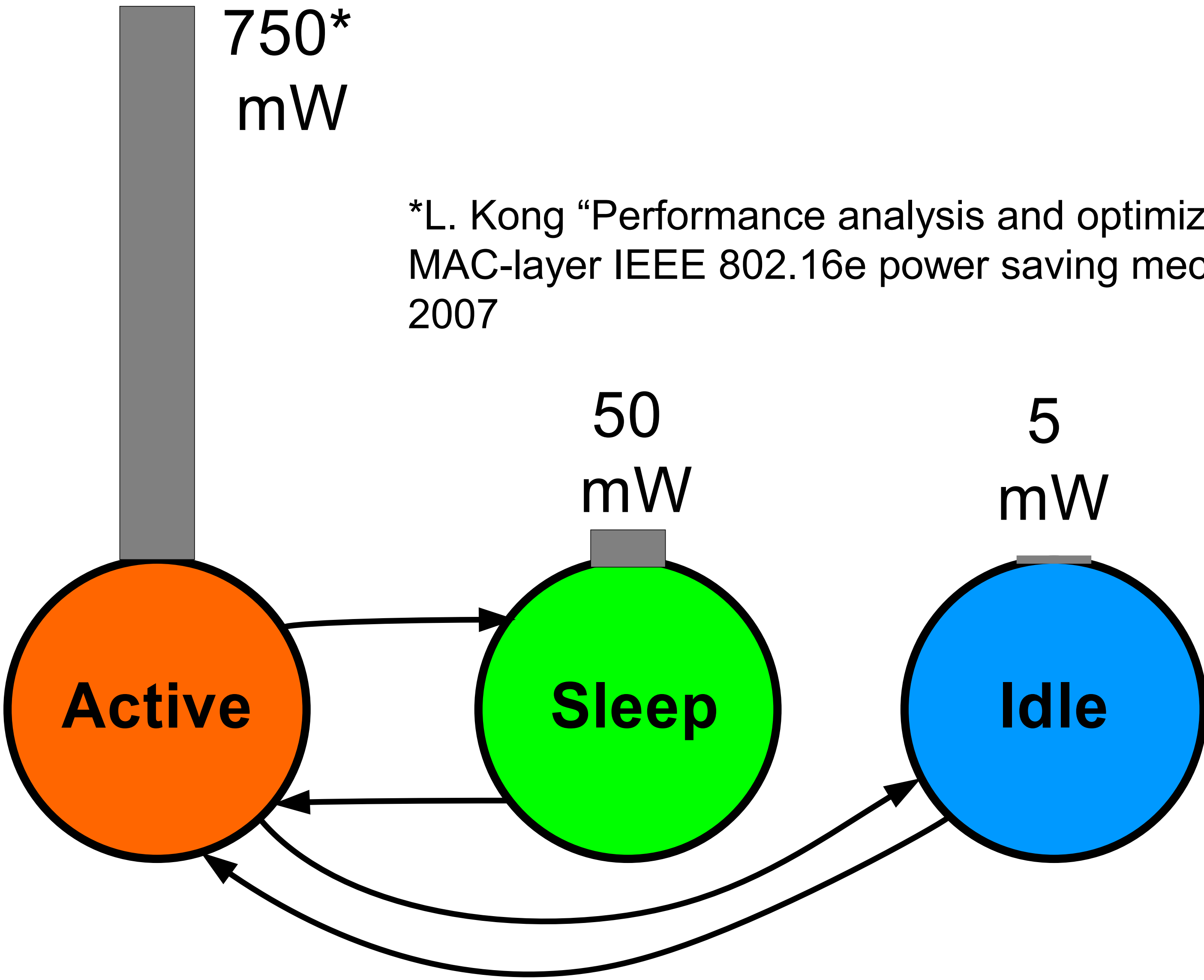
IEEE 802.16 Architecture

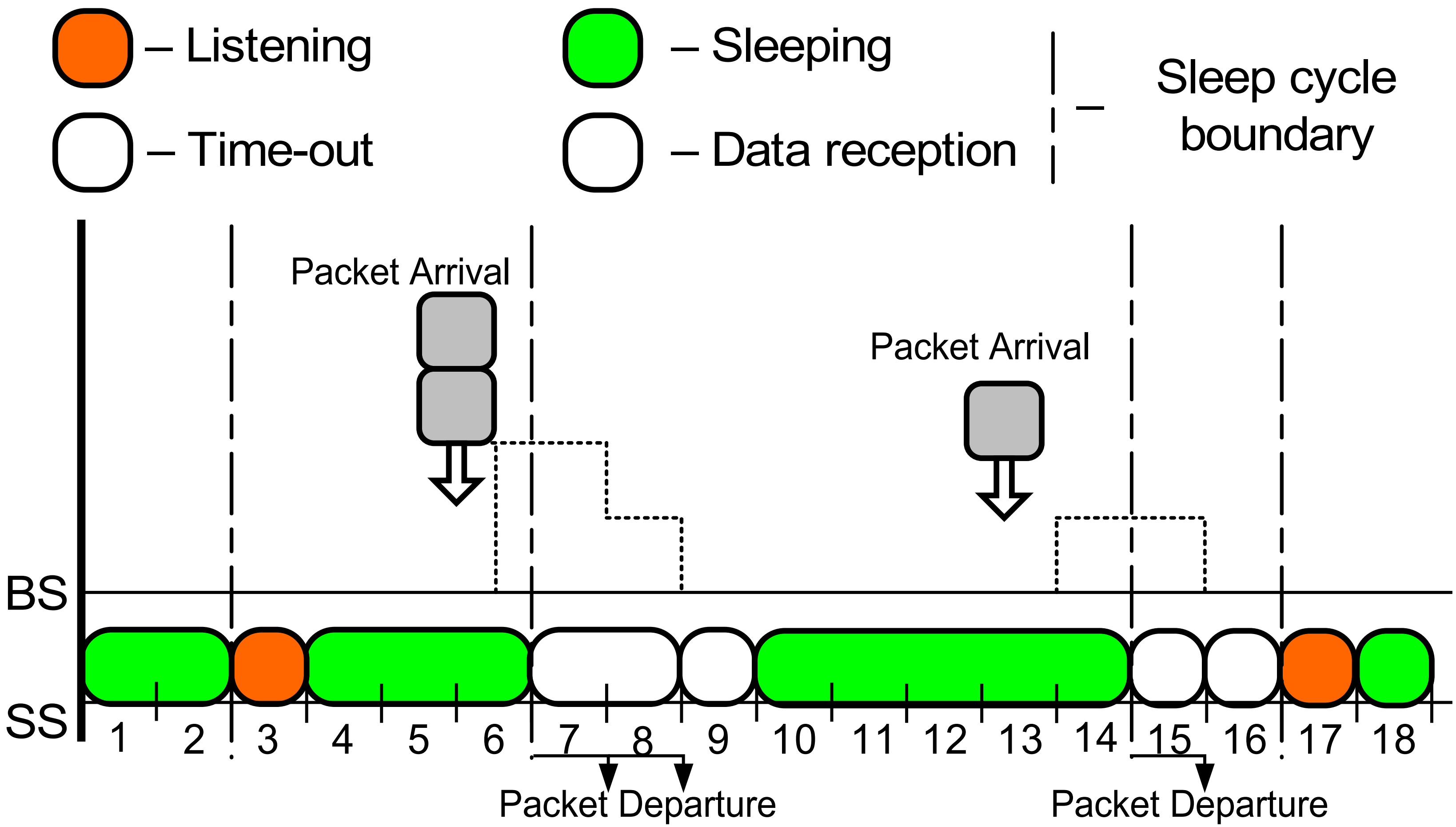


Energy Saving Modes



*L. Kong “Performance analysis and optimization for MAC-layer IEEE 802.16e power saving mechanism”, 2007

Sleep Mode Operation



Reason for the Study

IEEE 802.16 standard defines only sleep mode control algorithm and doesn't provide any recommendations how to choose its parameter values.

Here we present a mechanism how to choose parameters values for the sleep mode.

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Energy Efficiency Estimation

- ***Number of bits that may be received successfully by spending one Joule of energy***

$$U \triangleq \lim_{t \to \infty} \frac{\text{Received bits within t}}{\text{Energy consumption within t}} \left(\frac{\text{Bits}}{\text{Joule}}\right)$$

here t is observation period

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QoS Parameters in WiMAX

Service Flow	Defining QoS	Examples
Unsolicited grant services (UGS)	Maximum sustained rate Maximum latency Jitter tolerance	VoIP without silence suppression
Extended real-time Polling service (ErtPS)	Minimum reserved rate Maximum sustained rate Maximum latency Jitter tolerance	VoIP with silence suppression
Real-time Polling service (rtPS)	Minimum reserved rate Maximum sustained rate Maximum latency	Streaming audio and video, MPEG encoded
Non-real-time Polling service (nrtPS)	Minimum reserved rate Maximum sustained rate	File Transfer Protocol (FTP)
Best-effort service (BE)	Maximum sustained rate	Web browsing, data transfer

Sample Traffic Parameters*

Parameter	Voice	Video	Data
Data rate	4Kbps-64Kbps	> 1Mbps	0.01Mbps-100Mbps
Traffic flow	Real-time continuous	Continuous	Non-real time, bursty
Packet loss	< 1%	$< 10^{-8}$	Zero
Delay variation	< 20ms	< 2 sec	N/A
Delay	< 100 ms	< 100 ms	Flexible

*from “Fundamentals of WiMAX”

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General Optimization Task

The sleep mode operation not only decreases the power consumption of an SS, but also has a negative impact on QoS parameters

Maximize

energy efficiency U

Under the restriction

QoS parameters (latency, minimum reserved rate, jitter)

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System Model Assumptions

- *BS and a single SS is taken into account*
- *Downlink traffic (from the BS to the SS)*
- *One packet is served per one frame*
- *Poisson arrivals flow*
- *Only mean delay restriction is taken into account*

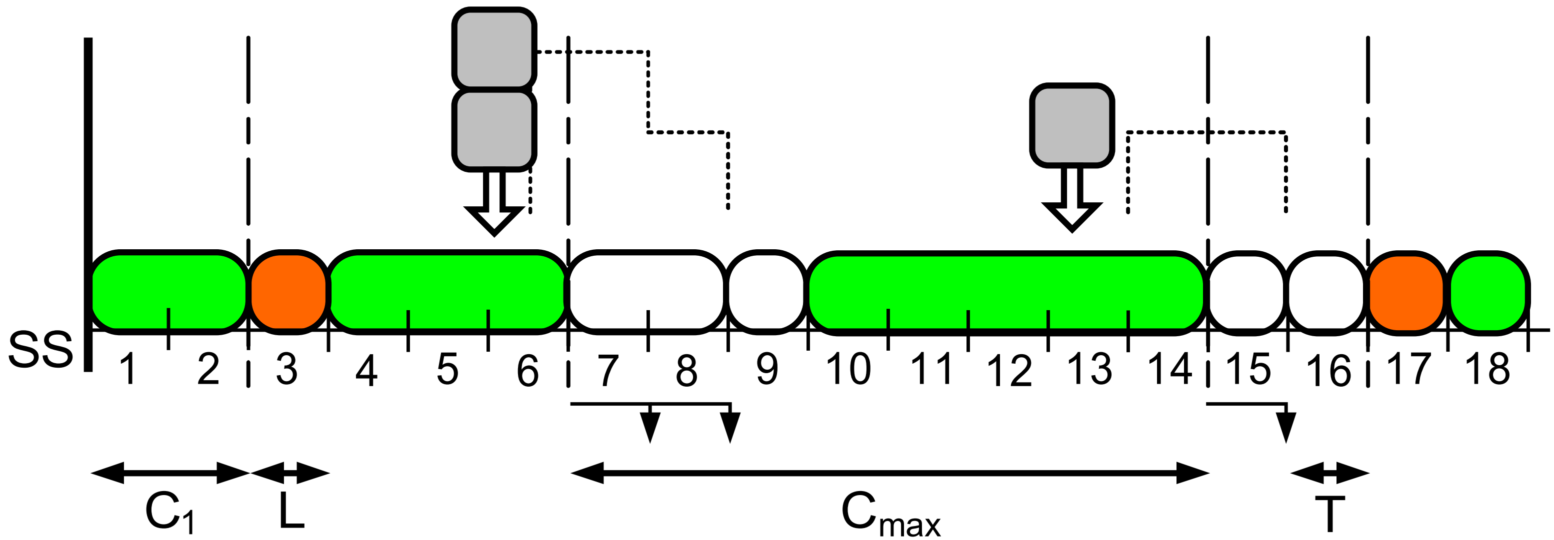
Particular Optimization Task

C_1 - initial sleep cycle

L – listening period

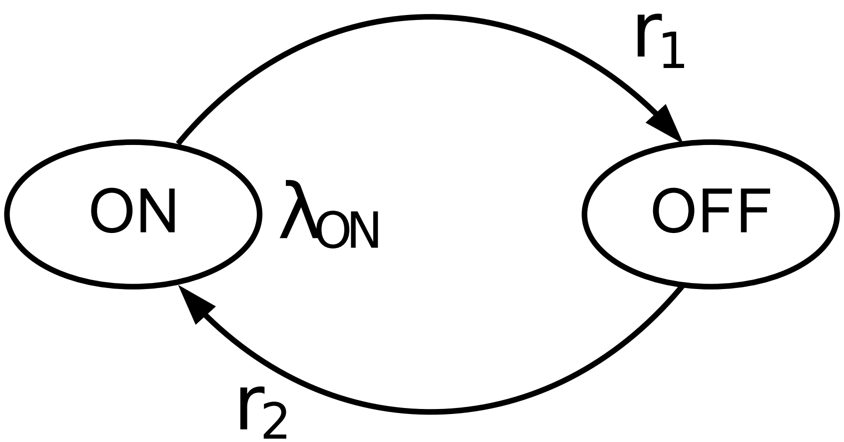
C_{max} – maximum sleep cycle

T - timeout



For certain rate λ choose sleep mode parameters C_1, C_{max}, L, T to maximize energy efficiency $U(C_1, C_{max}, L, T, \lambda)$ under the restriction $D(C_1, C_{max}, L, T, \lambda) \leq D_{max}$

System Model with HTTP Traffic



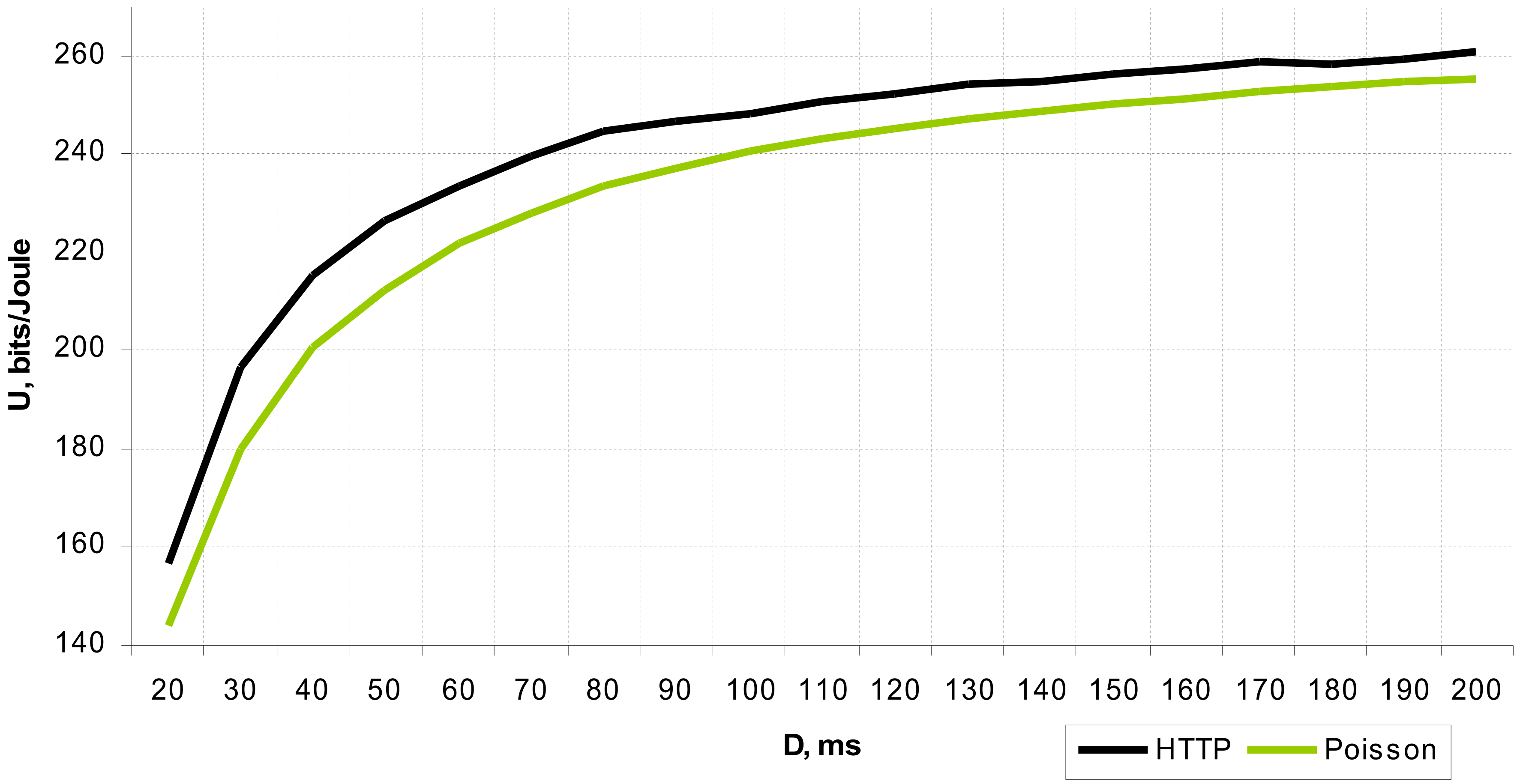
λ_{ON} – mean rate in the ON state
r_1,r_2 – transition rate from ON to OFF and vice versa

Updated optimization task

For certain rate λ_{ON}, transition rates r_1, r_2 choose C_1, C_{max}, L, T to maximize energy efficiency $U(C_1, C_{max}, L, T, \lambda_{ON}, r_1, r_2)$

under the restriction $D(C_1, C_{max}, L, T, \lambda_{ON}, r_1, r_2) \leq D_{max}$

Energy Efficiency



Mean rate λ is constant. Results for Poisson arrivals were obtained by a numerical analysis

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Conclusion

- Formulated general optimization task
- Proposed model with Poisson arrival flow
- Obtained the numerical analysis for the model
- Proposed model with HTTP arrival flow
- Compared results for Poisson arrivals and HTTP arrivals

Future Works

- Take into account another QoS parameters
- Develop a numerical analysis for different traffic models (VoIP, HTTP, etc.)
- Make the model closer to real life (several SSs, more difficult scheduler etc.)

Thank you!