Analysis of Discontinuous Reception Based Energy-Saving Technique

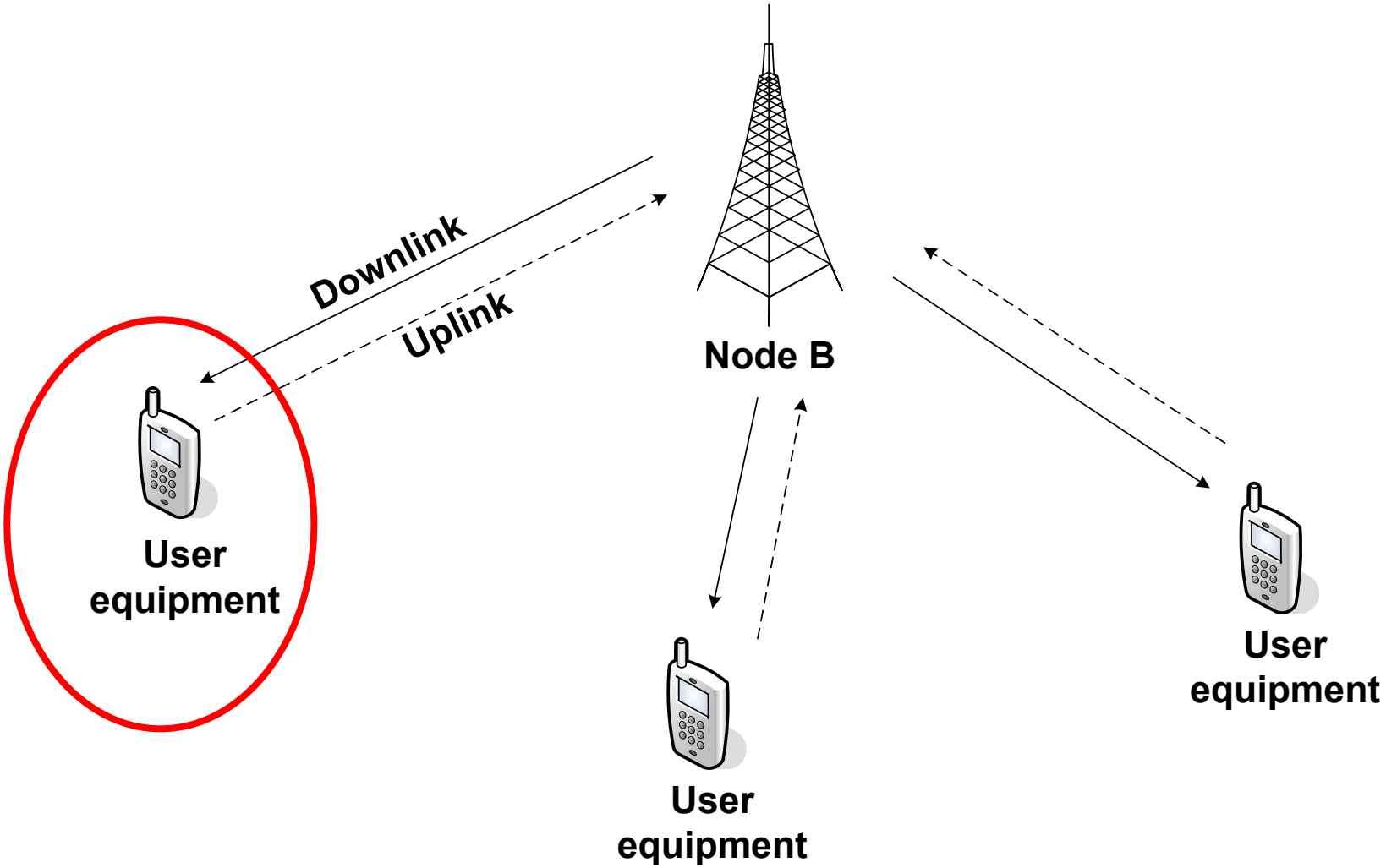
Evgeny Pustovalov, eugeny@vu.spb.ru
Prof. Andrey Turlikov, turlikov@vu.spb.ru
Saint-Petersburg State University of Aerospace Instrumentation

Agenda

- Power saving in 3G/4G networks
  - Discontinuous reception (DRX)
  - Energy consumption / delay tradeoff
- DRX analysis
  - Traffic model
  - Analysis of DRX
  - Numerical results

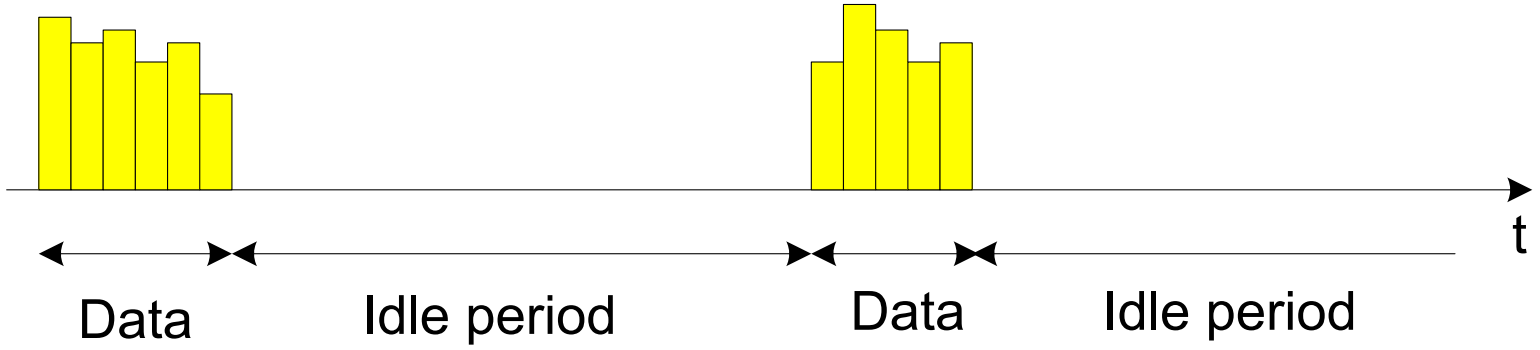
Centralized 3G/4G network (HSPA, LTE, etc)

- Energy saving of user's battery is considered



Energy saving in 3G/4G

- Bursty traffic (downlink traffic is considered)



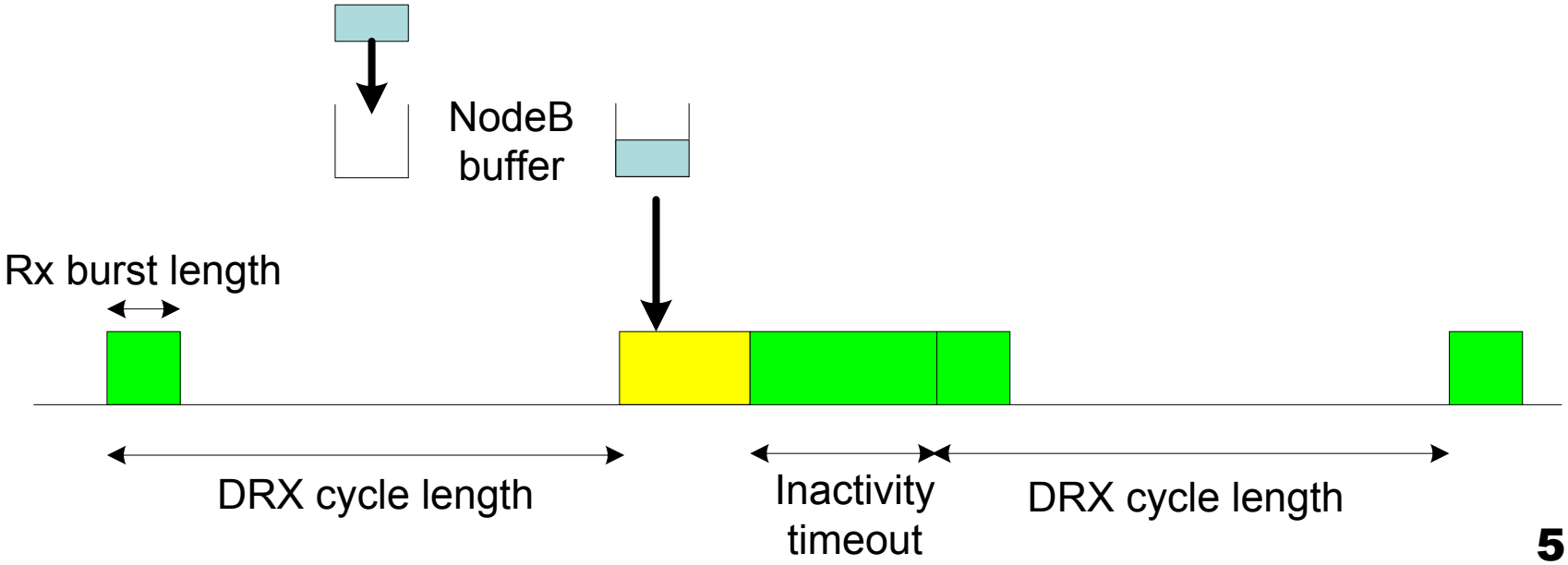
- How to save user (UE) energy if downlink traffic is bursty ?
  - Solution: turn off UE receiver during Idle period
  - How it is implemented in 3G/4G networks: discontinuous reception (DRX)

Discontinuous reception - DRX

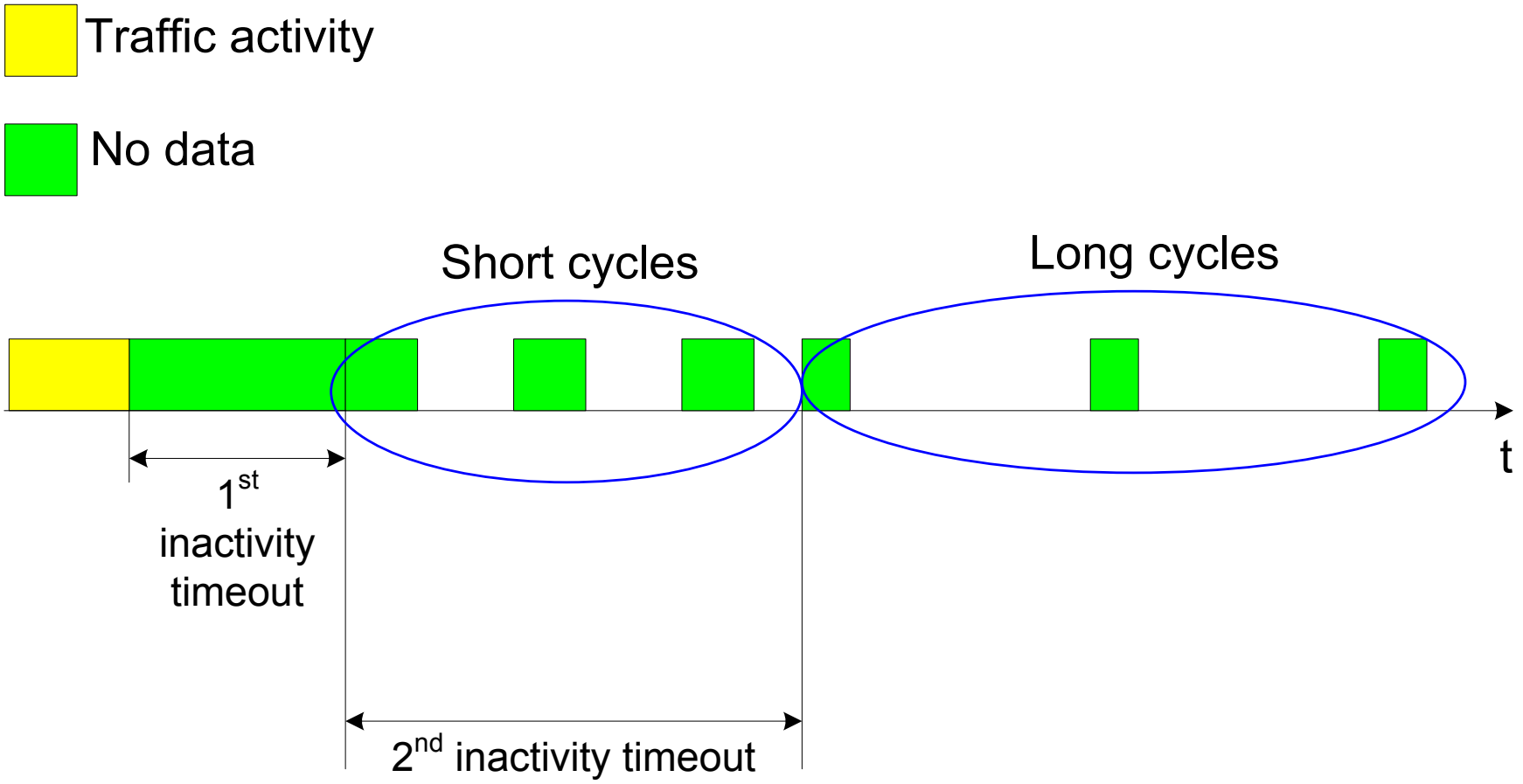
Receive data

Listen to the channel (no data)

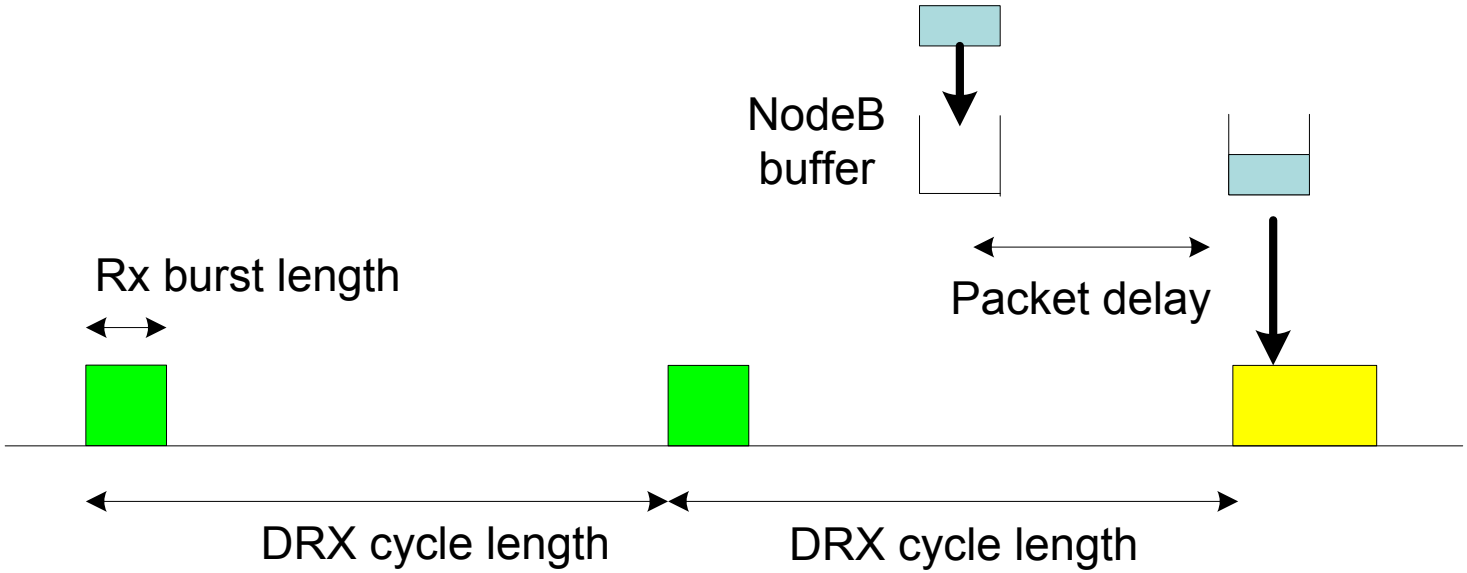
A message



Two-level DRX



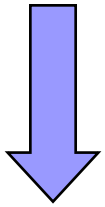
DRX energy saving/delay tradeoff



- Longer DRX cycle:
  - More energy saving gain
    - DRX cycle length / Rx burst length
  - Longer delay
- **What is optimal DRX parameters ?**

Research target

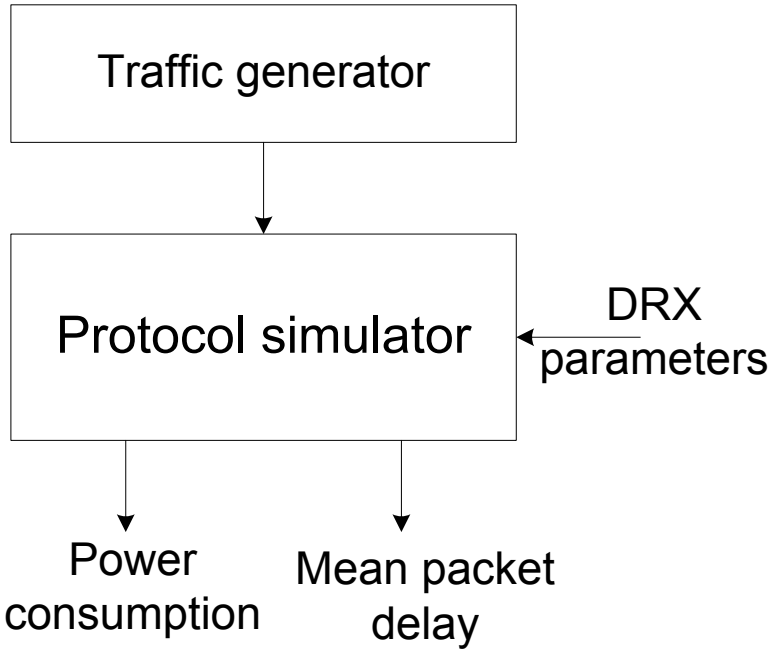
- Quality of Service => minimal delay



- Find DRX parameters which
  - Minimize power consumption
  - Where mean delay < threshold

Solution (1): protocol simulator

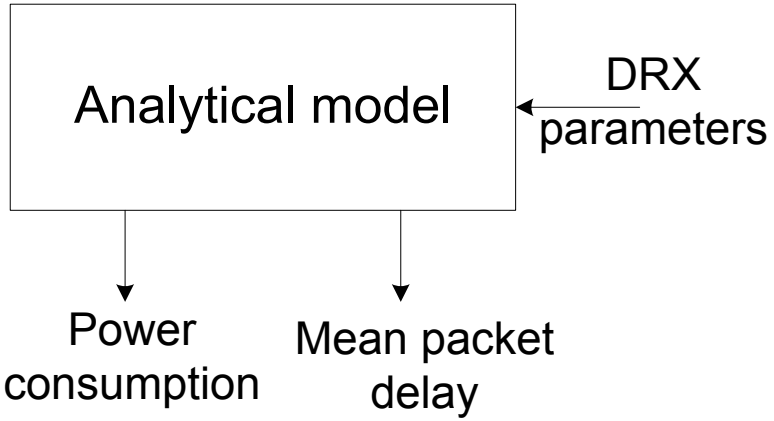
- For all set of DRX parameters
  - Simulate system with one set of parameters



- Find parameters corresponding to minimal power consumption under given constraint on delay

Solution (2): analytical model

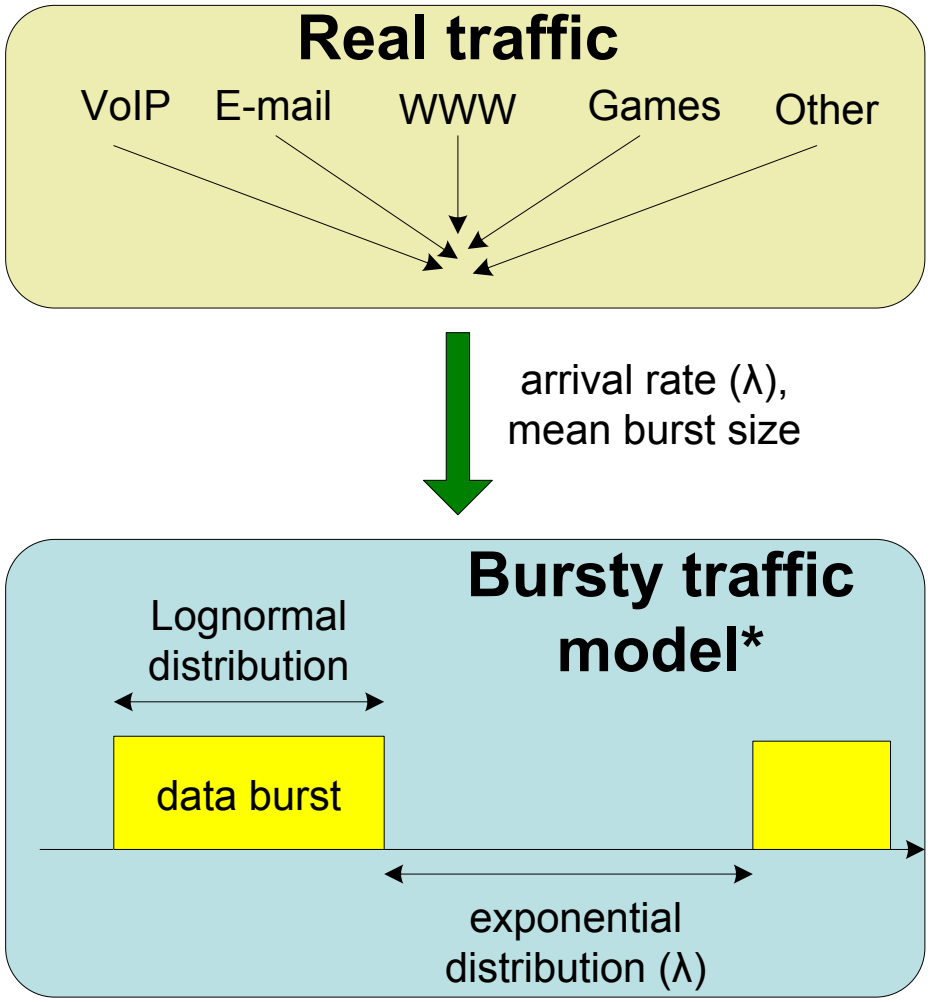
- For all set of DRX parameters
  - Get power consumption/delay via equations



- Find parameters corresponding to minimal power consumption under given constraint on delay

- **Here we consider analytical analysis**
  - Mathematical traffic model is required

Traffic model



* 3GPP TR 25.825, Dual-Cell HSDPA operation

Power consumption

η_{OFF} - portion of time UE does not listen to the channel (OFF state)

$\eta_{ON} = 1 - \eta_{OFF}$ - portion of time UE is active (ON state)

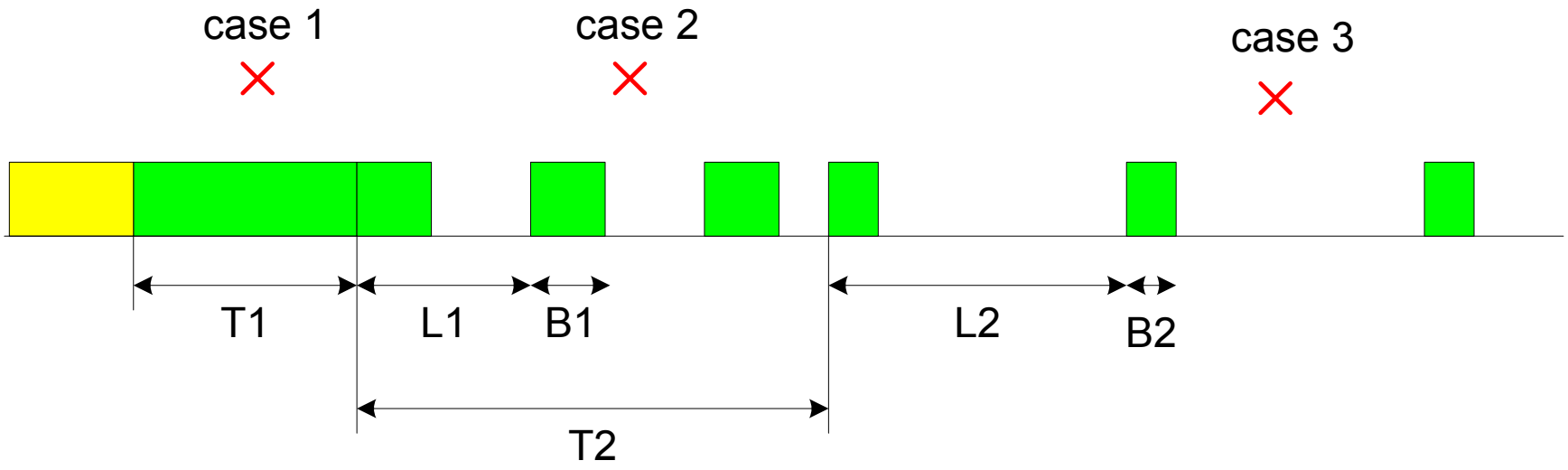
$$P = \eta_{Rx}\zeta_{ON} + \eta_{OFF}\zeta_{OFF}$$

where

ζ_{ON} - power consumption in ON state

ζ_{OFF} - power consumption in OFF state $\left(\zeta_{OFF} << \zeta_{ON}\right)$

Two-level DRX analysis



1) New packet arrives before T1 expires

$$p1 = P(t < T1) = 1 - e^{-\lambda T1}$$

2) New packet arrives after T1 expires and before T2 expires

$$p2 = P(T1 < t < T1 + T2) = e^{-\lambda T1} - e^{-\lambda(T1+T2)}$$

3) New packet arrives after T2 expires

$$p3 = P(t > T1 + T2) = e^{-\lambda(T1+T2)}$$

Two-level DRX analysis

$$\bar{d} = p_2\left(\frac{L_1}{2} - B_1 + \frac{B_1^{\,2}}{2L_1}\right) + p_3\left(\frac{L_2}{2} - B_2 + \frac{B_2^{\,2}}{2L_2}\right)$$

$$\eta_{DRX1} = \frac{\left(\dfrac{-e^{-\lambda T_2}(T_2 + 1/\lambda) + 1/\lambda}{1 - e^{-\lambda T_2}} + \bar{d}_1\right) p_2 + p_3 T_2}{\left(\bar{S}/R + 1/\lambda\right) + \bar{d}}$$

$$\eta_{DRX2} = \frac{(1/\lambda + \bar{d}_2)\, p_3}{\bar{S}/R + 1/\lambda + \bar{d}}$$

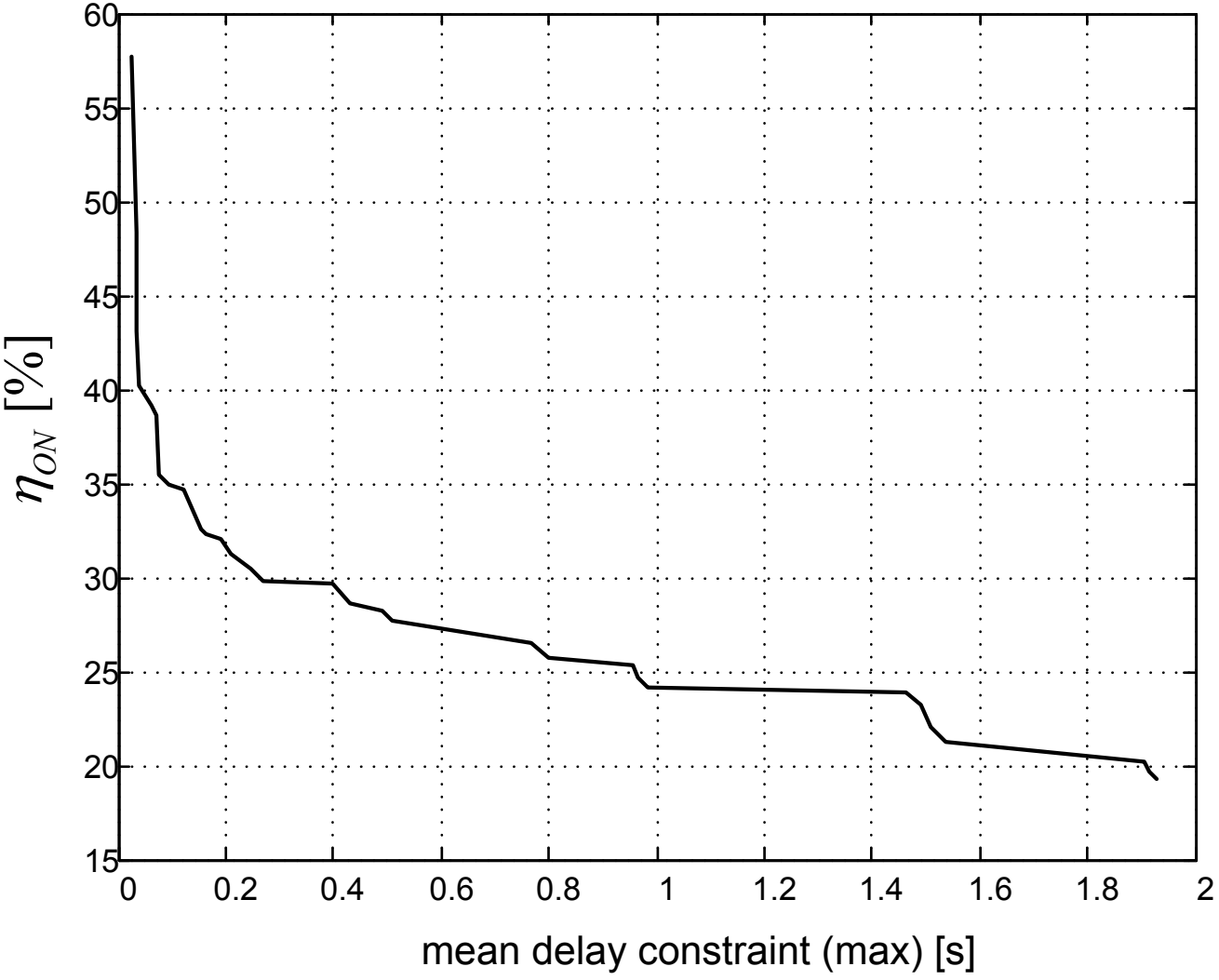
$$\eta_{OFF} = \eta_{DRX1}\frac{L_1 - B_1}{L_1} + \eta_{DRX2}\frac{L_2 - B_2}{L_2}$$

Set of test DRX parameters

- Illustrate methodology by HSPA DRX

Parameter	Value
Throughput	100 Kbit/sec
Mean data size	10 KByte
Mean inter-arrival rate	2 sec
Short cycle length L1	80 / 160 / 320 ms
Long cycle length L2	640 / 1280 / 2560 / 5120 ms
Short cycle wakeup period B1	10 ms
Long cycle wakeup period B2	2 / 4 / 6 / 8 / 10 ms
Short cycle timeout T1	100 / 200 / 400 / 800 ms
Long cycle timeout T2	0.5 / 1 / 2 / 5 s

Numerical results



Conclusion

- Power saving via DRX was considered
- DRX introduces performance tradeoff
  - Energy consumption vs packet delay
  - Research target: find optimal DRX parameters
- Analytical approach
  - Approximate traffic via mathematical model
  - Derive equations to find energy consumption and delay
    - Replace exhausted simulations

Thanks! Questions?