Optimal uplink subframe structure for WiMAX MAC protocol in PMP mode

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On-demand resource allocation in WiMAX

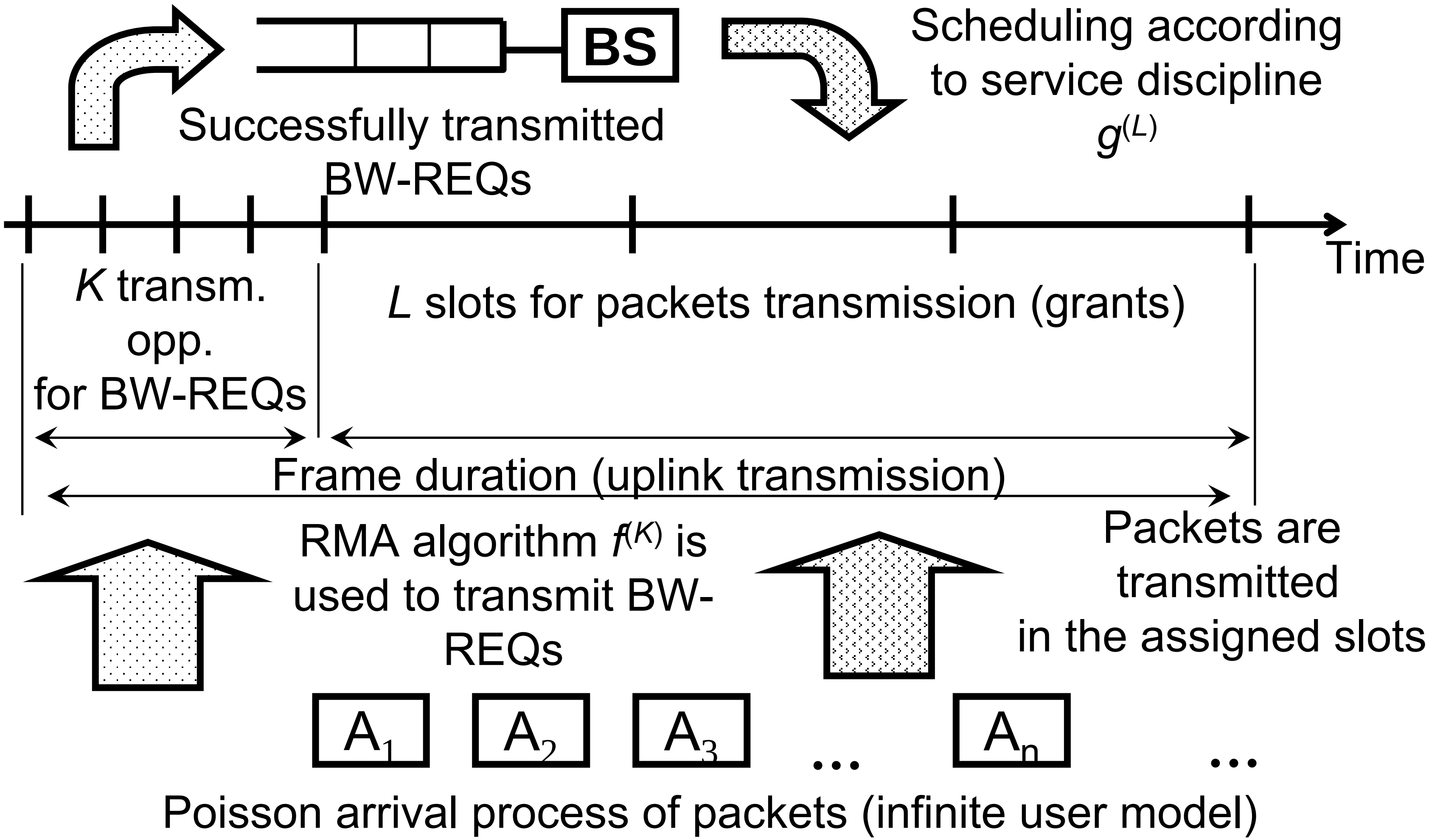
- Bandwidth request (BW-REQ):
  - 48 bit message sent by subscriber station to inform base station about required uplink resource allocation
- Polling:
  - Allocation of uplink resources for transmitting a single bandwidth request
  - Unicast: allocation to a single subscriber station
  - Multicast: allocation to a group of subscriber stations
  - Broadcast: allocation to all subscriber stations
- Grant:
  - Allocation of uplink resources to a single subscriber stations for transmitting data
- Piggybacking
  - Possibility to attach a bandwidth request to a data transmission

Scheduling types in WiMAX

Scheduling type of a connection
defines a mechanism how uplink resources are allocated to a connection with associated QoS parameters

- Unsolicited Grant Service (UGS)
  - fixed resource allocation
  - **direct grants**
- Real-Time Polling Service (rtPS)
  - on-demand resource allocation with coordinated bandwidth requests
  - **unicast polling**
- Non-Real-Time Polling Service (nrtPS), Best Effort (BE)
  - on-demand contention-based resource allocation
  - **broadcast polling, piggybacking**
- Extended Real-Time Polling Service (ertPS)
  - hybrid resource allocation
  - **direct grants** and **unicast polling**

Model for the on-demand contention-based resource allocation



Performance metrics of interest

I. Mean packet transmission delay:

$$D(\lambda, K, L, f^{(K)}, g^{(L)}) = \overline{\lim}_{n\to\infty} E\delta_n = \overline{\lim}_{n\to\infty} E(\delta_n^{(1)} + \delta_n^{(2)})$$

BW-REQ reservation delay → $\delta_n^{(1)}$

BS bandwidth allocation delay → $\delta_n^{(2)}$

$$D_1 = \overline{\lim}_{n\to\infty} E\delta_n^{(1)}$$

II. Transmission rate of MAC protocol:

$$R(K, L, f^{(K)}, g^{(L)}) = \sup_{\lambda} \{\lambda : D(\lambda, K, L, f^{(K)}, g^{(L)}) < \infty\}$$

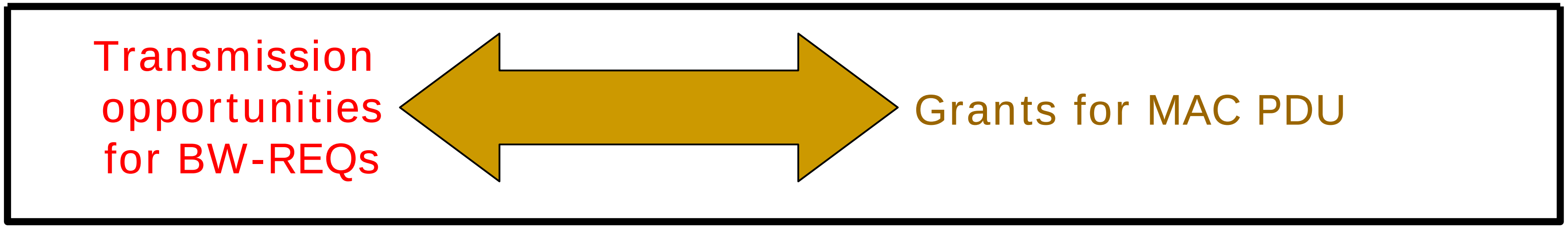
III. Capacity of a network

$$C(K, L, F^{(K)}, G^{(L)}) = \sup_{f^{(K)} \in F^{(K)}, g^{(L)} \in G^{(L)}} R(K, L, f^{(K)}, g^{(L)})$$

$F^{(K)}$ - the set of all RMA algorithms for K transmission opportunities

$G^{(L)}$ - the set of all allocation disciplines for L packet transmission slots

Problem statement



Fixed uplink sub-frame duration

2 opposite requirements:

Large number of transmission opportunities for reservation;

Large amount of bandwidth for MAC PDU;

What is *K* / *L* such as
a) Delay is minimal
b) Capacity is maximal?

Network capacity bounds derivation

Proposition 1. If $D_1 < \infty$, then $\lambda(\alpha K + L) < C_0 K$

Proposition 2. If $D < \infty$, then $\lambda(\alpha K + L) < L$

Proposition 3 (capacity upper bound):

$$\max_{K,L} C(K, L, F^{(K)}, G^{(L)}) \le \frac{1}{1 + \alpha / C_0}$$

Proposition 4 (capacity lower bound):

$$\max_{K,L} R(K, L, \phi^{(K)}, \varphi^{(L)}) = \frac{R_{pt}}{\alpha + R_{pt}}$$

with maximum achieved, when

$$K / L = 1 / R_{pt}$$

$\phi^{(K)}$ - the fastest algorithm (with rate R_{pt}) for the system with K transmission opportunities

$\varphi^{(L)}$ - FIFO service discipline

Theoretical areas of instability for the MAC protocol

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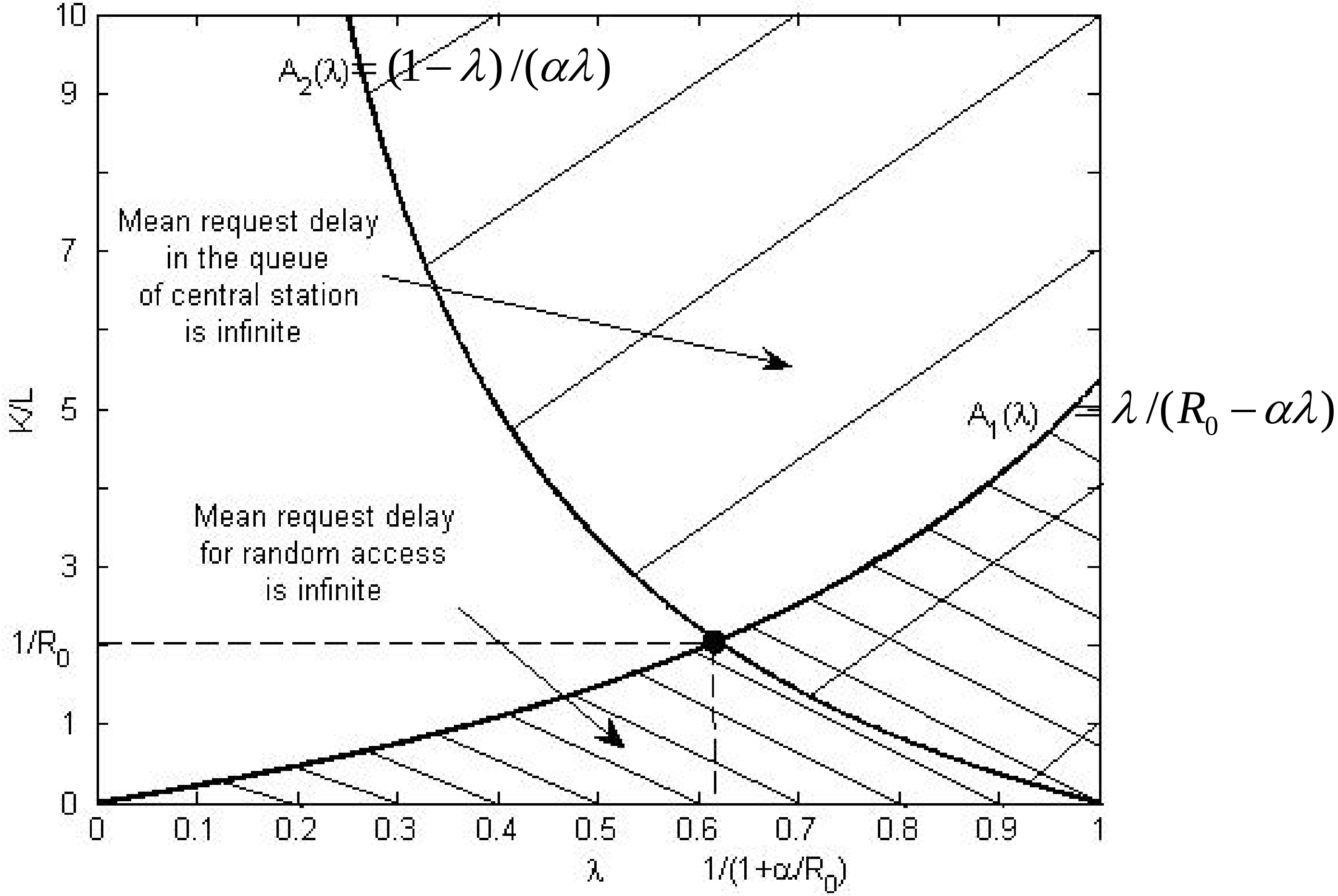
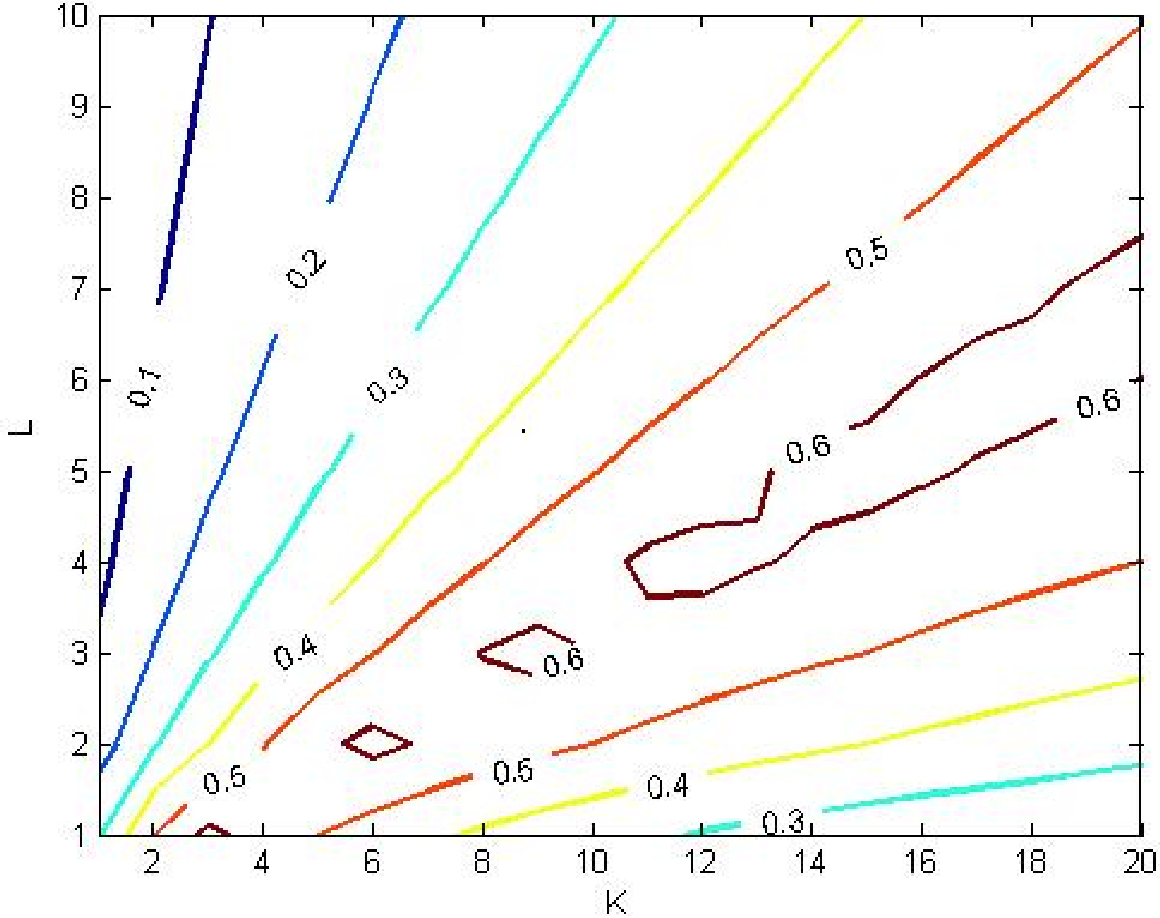


Theoretical WiMAX MAC protocol transmission rate bounds

$\alpha = 0.2$



It is assumed, that binary exponential backoff has finite transmission rate

$$\ln(2)/2$$

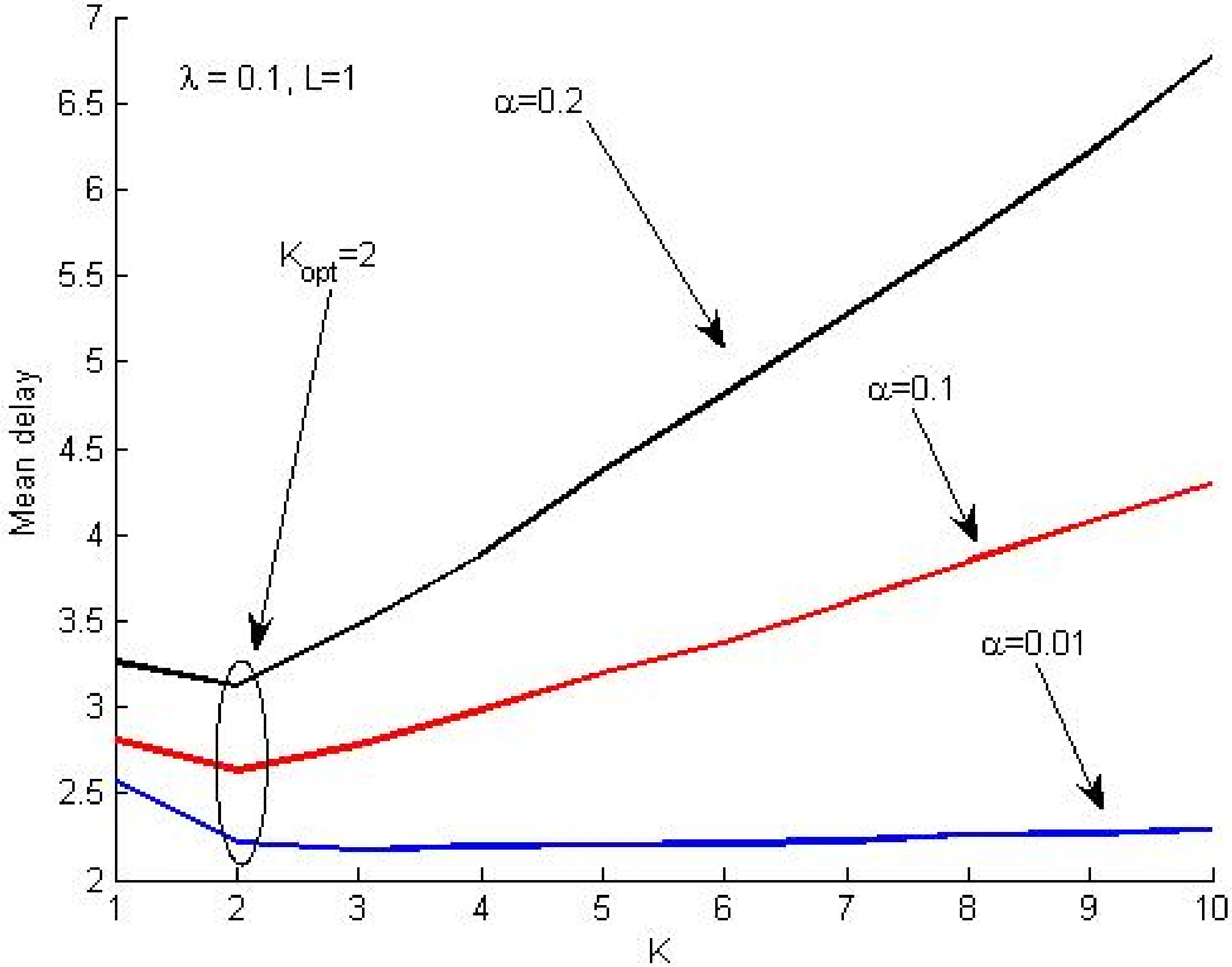
Conclusion:

For WiMAX MAC throughput is maximized when

***K / L* = 3**

Mean packet transmission delay

Example for low arrival rates



Mean packet transmission delay

Example for high arrival rates

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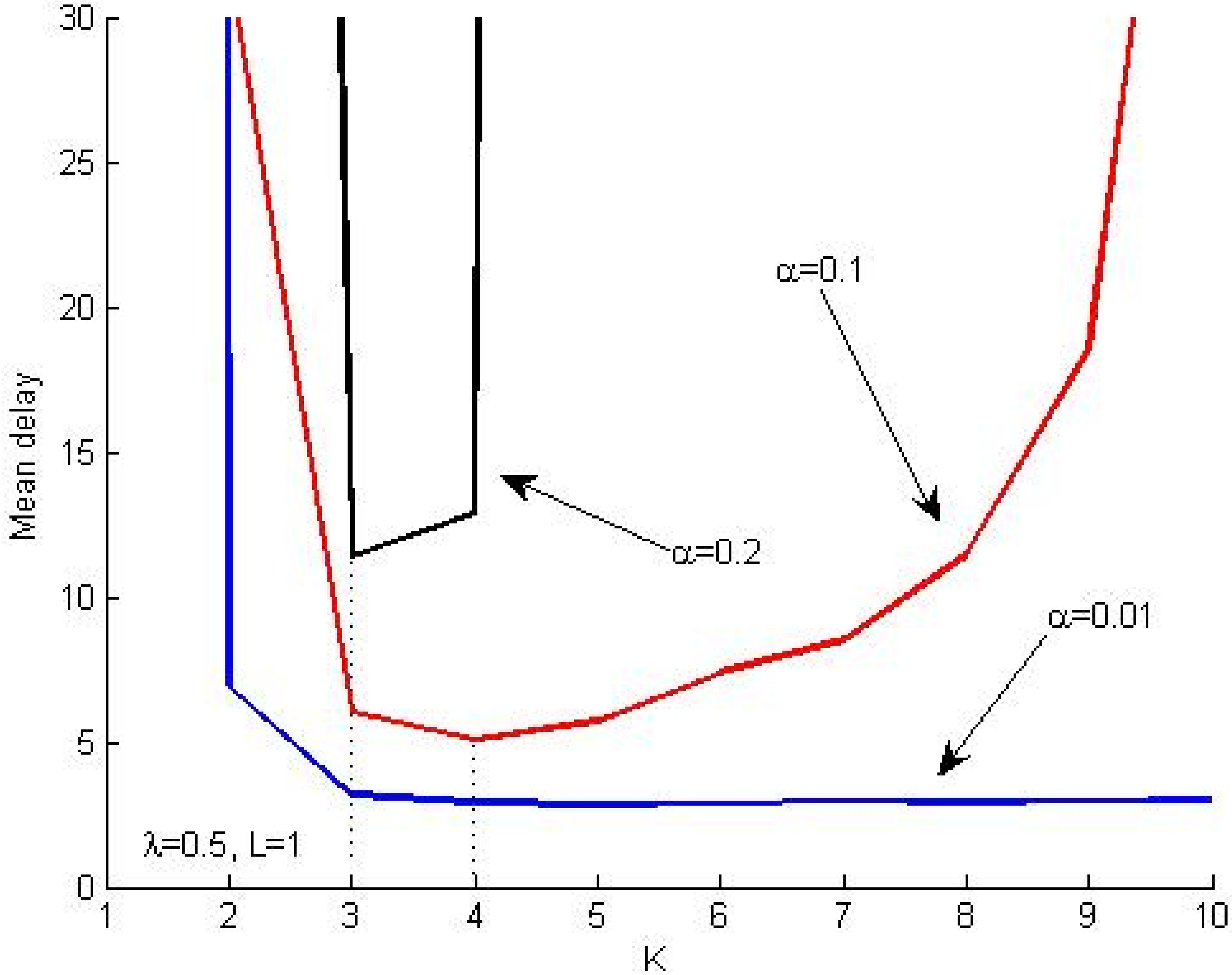

Optimal *K* and delay degradation for *K* = 3 as a reference point

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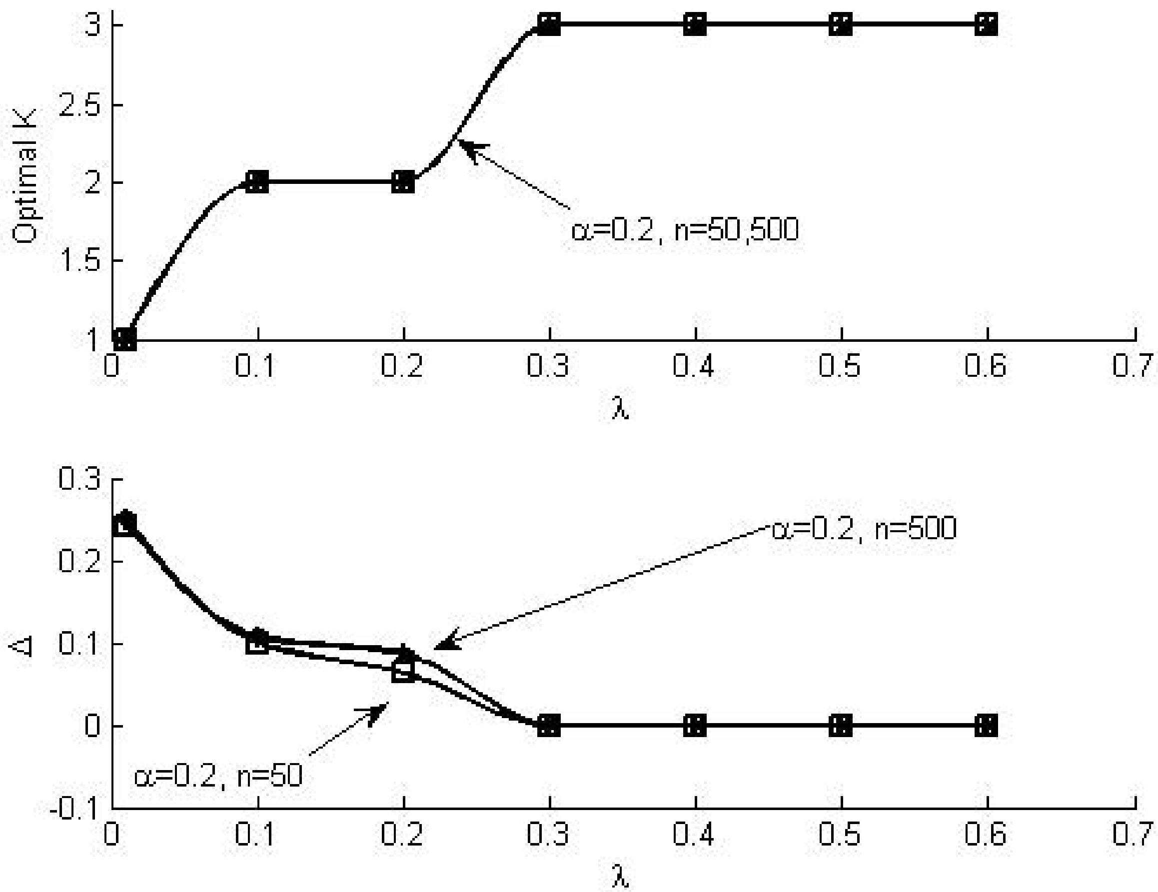

Conclusions

1 (Theoretical). It is shown, that maximal transmission rate of multiple access protocol equals to

$$1/(1+ \alpha / R_0)$$

and achieved when the ratio between number of slots *(L)* and mini-slots *(K)* per frame equals to R_0.

Here α is the ratio between the request and packet transmissions duration and R_0 is the rate of RMA algorithm.

2 (Practical - **WiMAX**). In the certain case of IEEE 802.16 MAC from both capacity and delay point of views it is reasonable to keep the ratio

***K/L* = 3**

constant independently of α and arrival rate value

Thanks for your attention!

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