

Modeling TCP in Multi-Rate Multi-User CDMA Systems

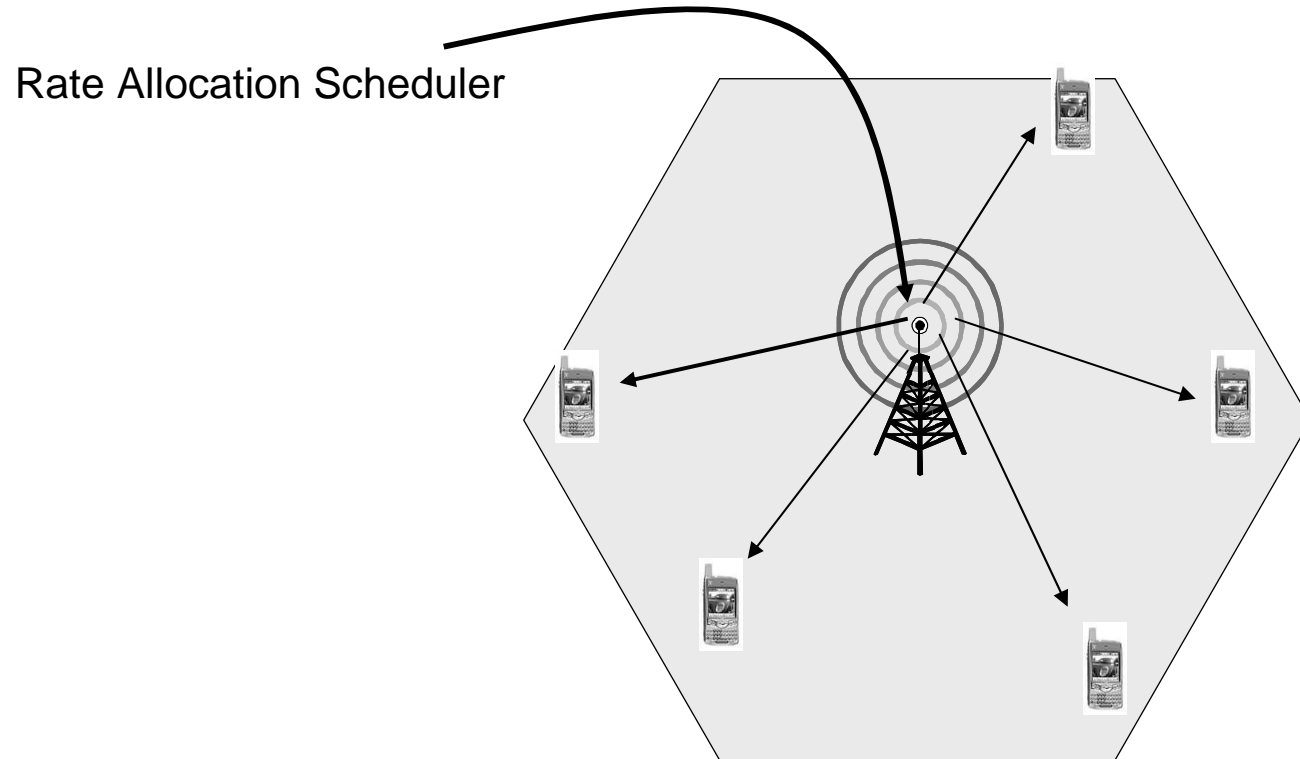
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Overview

- Modern cellular CDMA networks
 - Can dynamically assign variable rates to sessions.
 - Resource constraints imply not all sessions can simultaneously transmit at high rates.
- Model of TCP in such an environment.
 - Incorporate variable rate assignment.
 - Evaluate simple assignment policies.

Focus on Cellular Downlink



CDMA Data Networks

- Modern CDMA networks can support multiple rates **on-the-fly**.
- Each user assigned an 'orthogonal' Walsh Code.
 - Rate control by changing 'spreading code' length.
 - **Shorter** code words = **Higher** Data Rate.

CDMA Data Networks

- However, there is no free lunch.
- Resource Sharing Constraints.
- Shorter code more susceptible to channel errors, user interference.
- Supports **fewer** high-rate simultaneous sessions to preserve **orthogonality**.
- Fast power control mitigates short term channel variation.

An Example

- CDMA2000 1xRTT
 - Supports 30 users at 9.6 kbps (Fundamental Channel) with 1% FER.
 - At most 4 users simultaneously allocated 76.8 kbps channel (at 5-10% FER).
 - At most 2 users can be simultaneously allocated a 153.6 kbps channel (at 5-10% FER) called **Supplemental Channel**.

The Problem at Hand

- Multiple TCP sessions in a sector.
- Not all sessions can be given high-rate channels simultaneously.
- How do we arbitrate assignment of high-rate channels amongst them ?
 - What policy to use ?
 - How to evaluate impact of this policy ?
- Previous work has considered elastic sessions, but not TCP in particular.

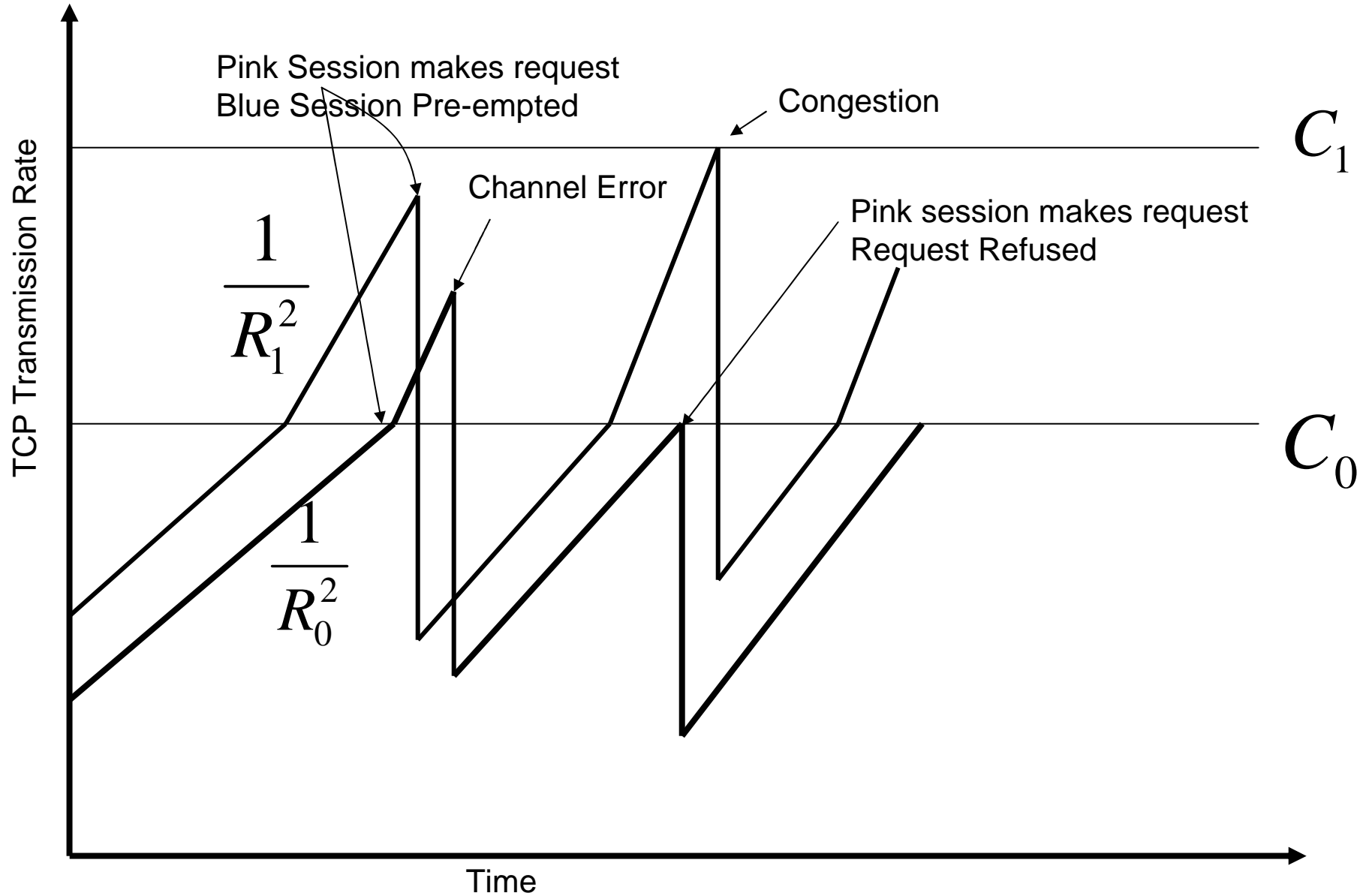
Applications

- Resource Allocation.
 - Which user(s) are assigned fast channels?
- Dimensioning
 - How many high-rate channels do we need?
- Spectrum Allocation.
 - What should be the value of the high rate channels ?

TCP Over CDMA - Characteristics

- TCP is a *reactive* protocol.
- TCP experiences variable RTT, variable channel errors.
 - **Not** random, may be correlated due to channel allocation policy [1].
- Sessions contend for high-rate channels
 - 'Losing' sessions experience congestion.
- Incorporate impact of allocation policy.

Multi-TCP Dynamics - 2 Channels



The Model - Assumptions

- High-rate codewords are orthogonal **within sector**
 - Do not affect other sessions.
- Sessions have same propagation delay.
- TCP modeled as a fluid
 - Model ignores slow start and time-outs
- We consider only **two** wireless channels.

The Model - Framework

- Let N be the number of fundamental channels = number of supported users.
 - Channel Error, Capacity = (p_0, C_0)
- Let K ($< N$) be the number of high-rate supplemental channels.
 - Channel Error, Capacity = (p_1, C_1)

$$p_0 \leq p_1, R_0 \geq R_1$$

- N **persistent** TCP Sessions.
- How to arbitrate allocation of K channels ?

α -Preemptive Policy

- If a session requests a high-rate channel and less than K supplemental channels occupied
 - Always assign high-rate channel.
- If all K supplemental channels occupied
 - Randomly pre-empt a high-rate session with probability α
 - Deny requesting session w.p. $1 - \alpha$
- System throughput a function of α , C_0 , C_1

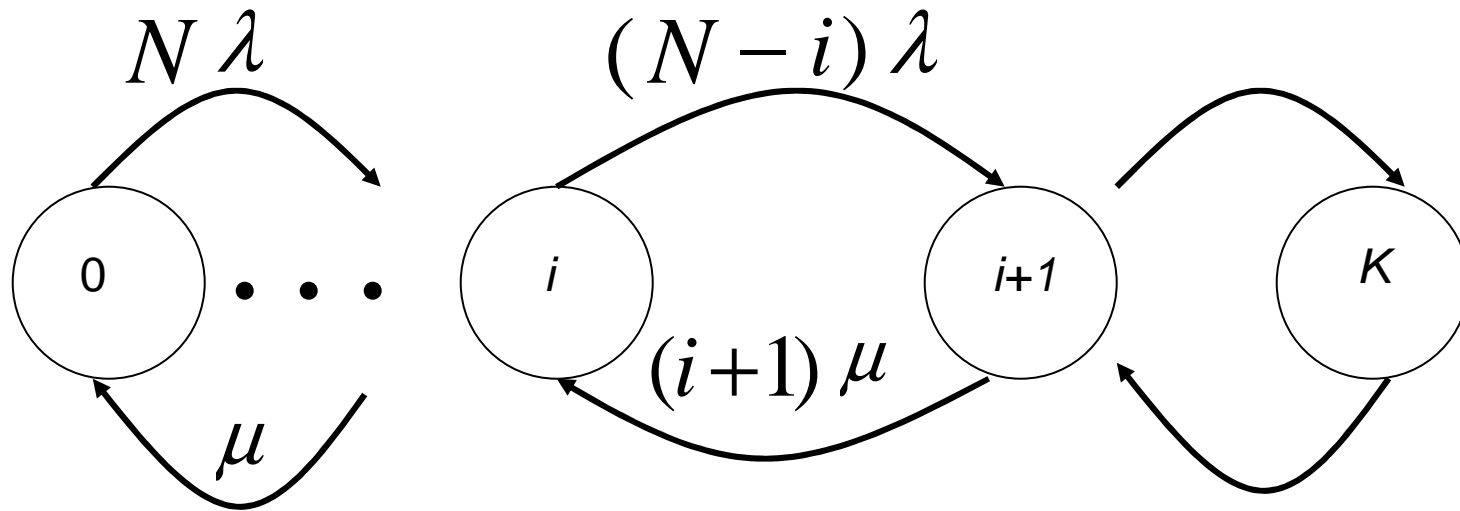
System Interactions

- The state of a TCP session (fundamental or supplementary)
 - Function of number of sessions occupying the supplementary channel.
- The number of sessions occupying the supplementary channel
 - Function of the rate of request from sessions in the fundamental channel state.

Fixed Point Model

- Model supplementary channel occupancy as a Markov chain.
 - Assume transition rates are known.
 - Compute likelihood ALL supplementary channels are fully occupied.
- *Each* TCP session evolution modeled in isolation.
 - Assume pre-emption rate known.
 - Variable channel rate TCP model from [2].
 - Modified model to include pre-emption.
 - Compute high-rate channel request rate.

Supplementary Channel Evol.

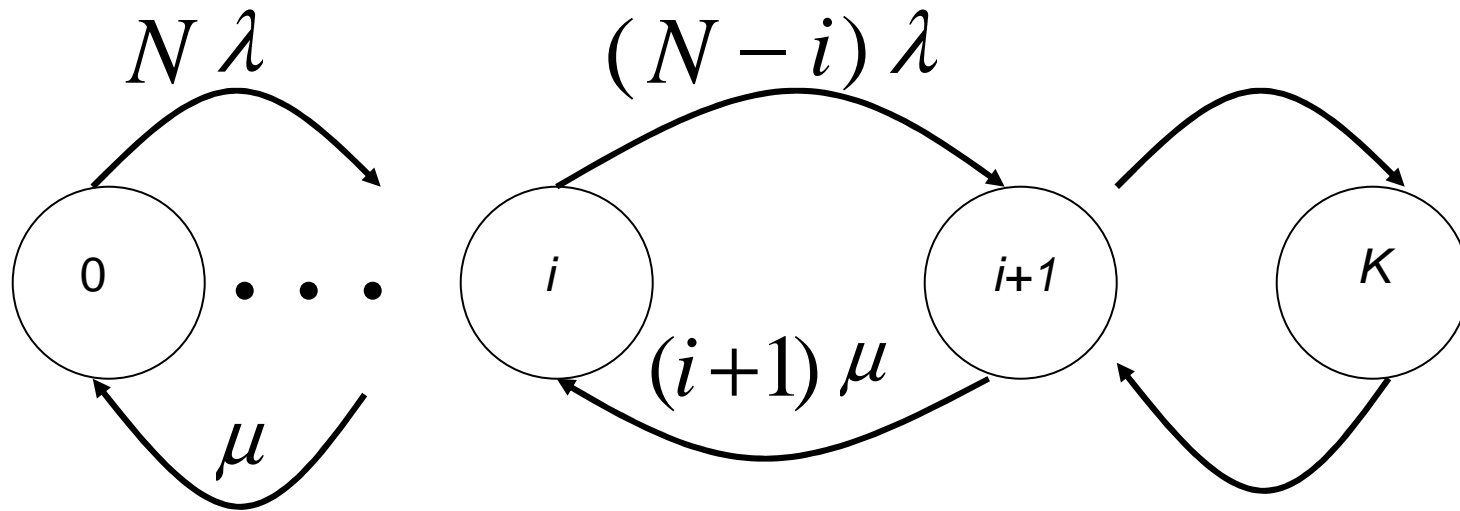


Input to TCP Model:

Probability Channel Request Honored = $\alpha\pi_K + (1 - \pi_K)$,

Pre - emption Rate (High to low) $\gamma = \left(\frac{N-K}{K}\right)\lambda\pi_K$

Supplementary Channel Evol.

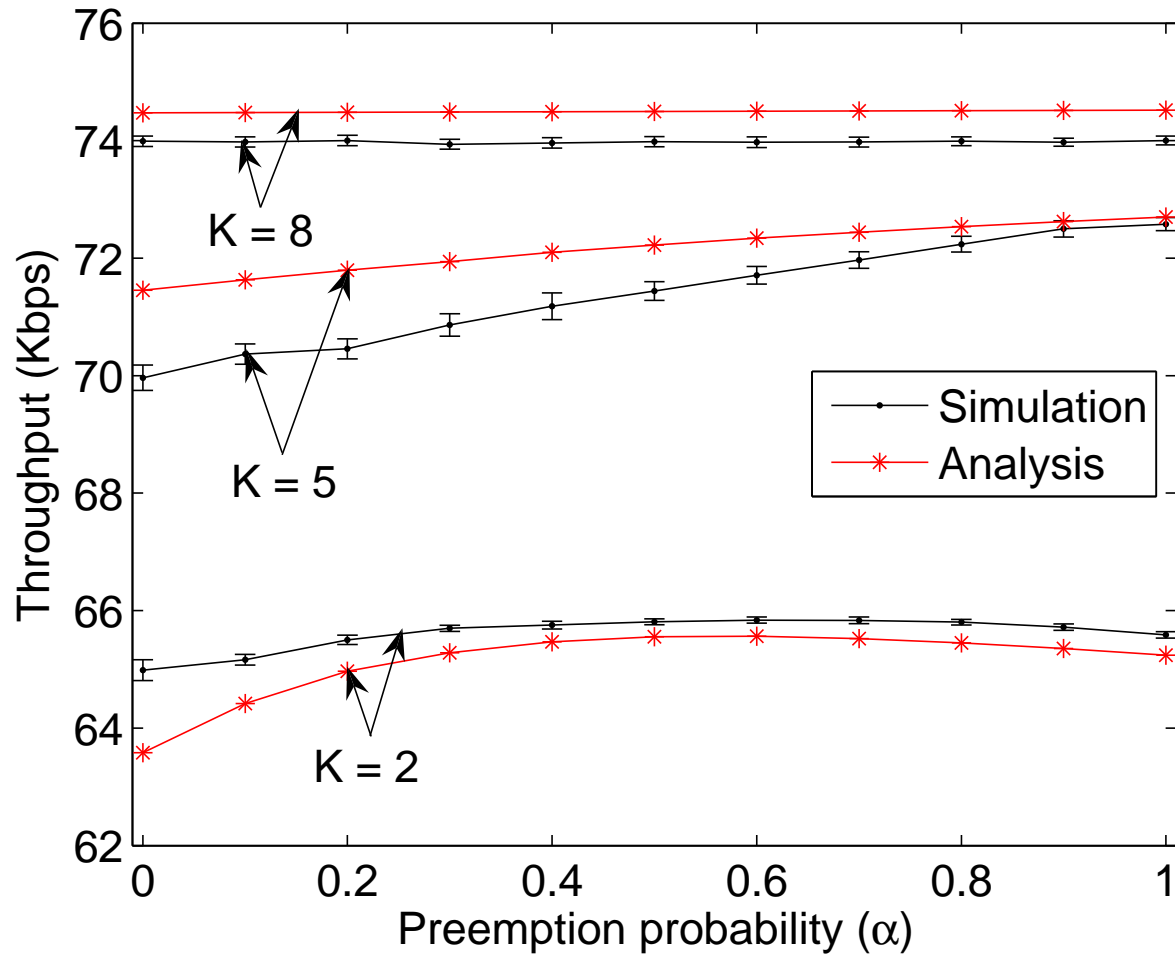


Input to Markov Chain :

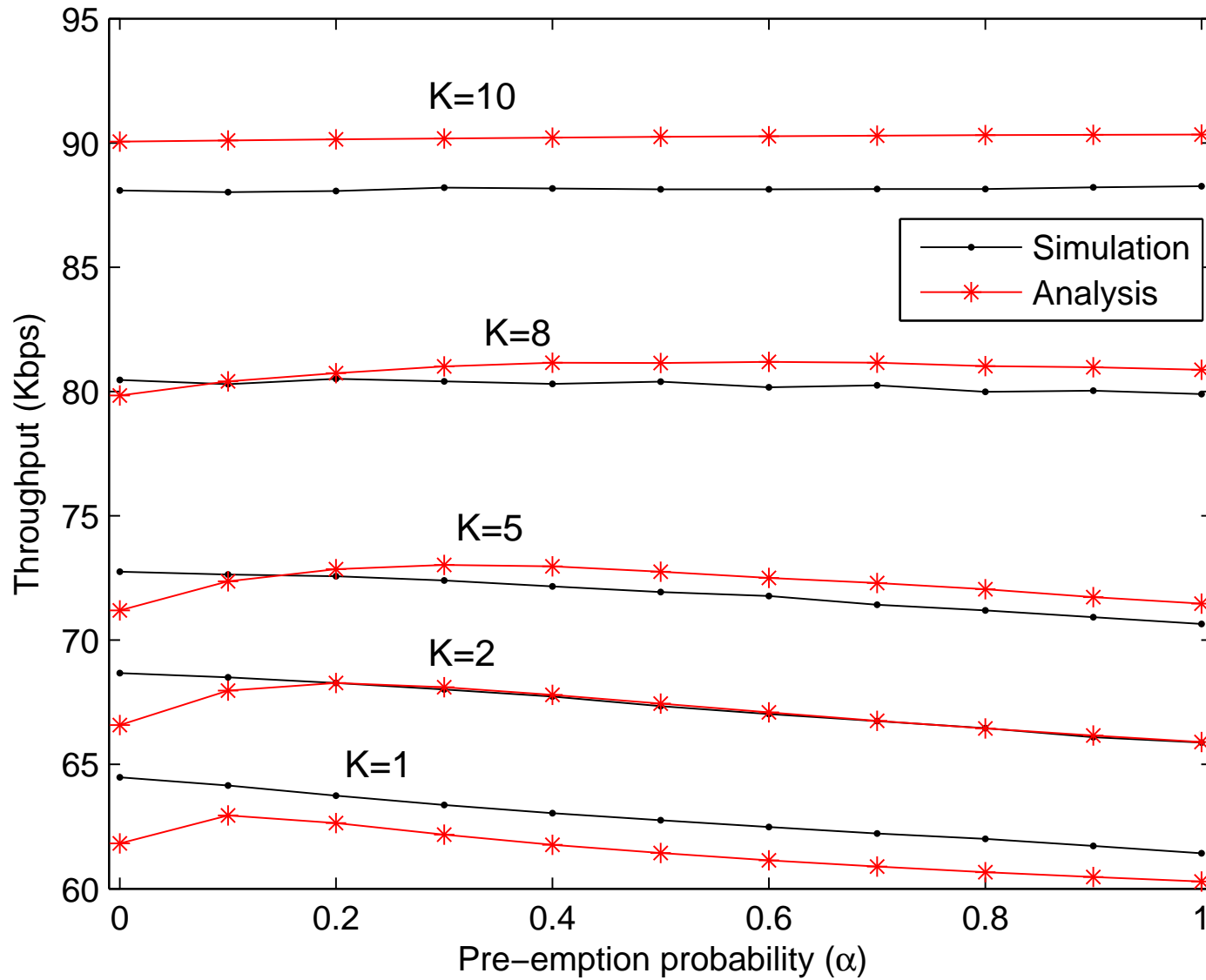
Supplemental Channel request rate : λ = Rate at which a TCP session requests the high - rate channel

Computed from TCP model

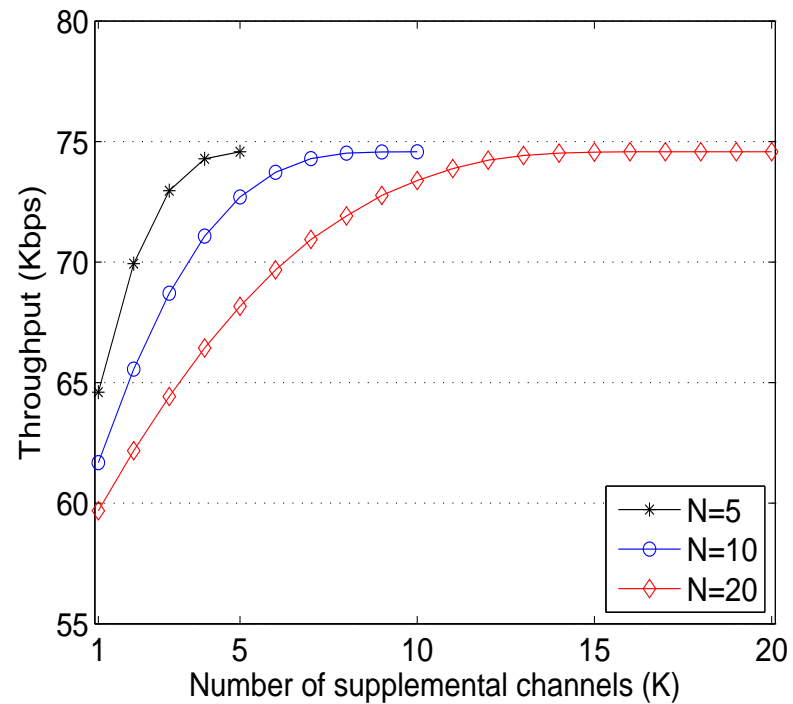
N=10, [76.8, 102.4]kbps



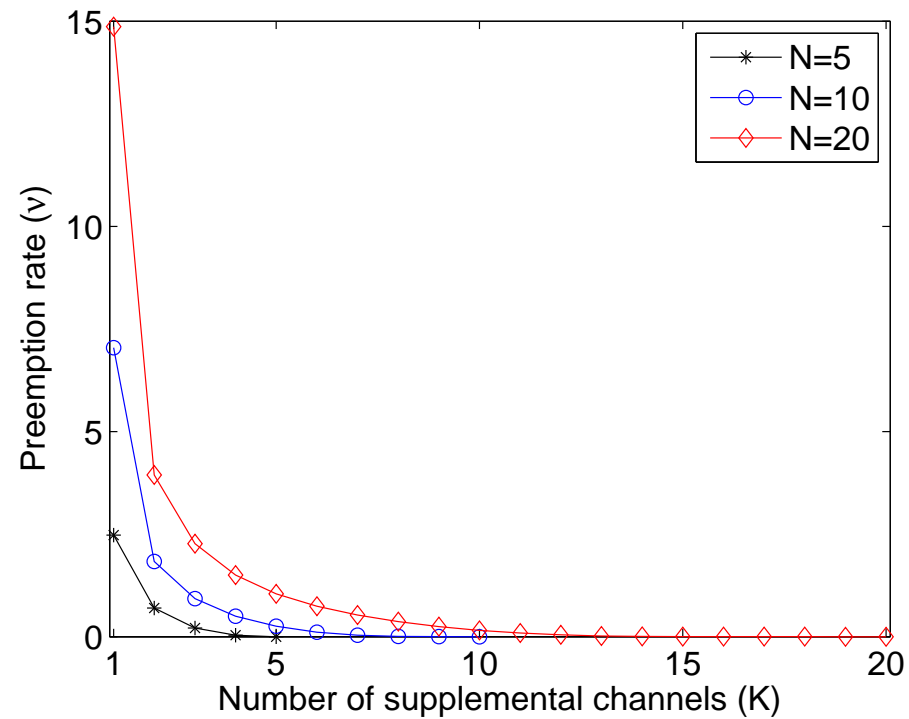
N=10 [76.8 153.6] kbps



Impact of K [76.8, 102.4]kbps



Impact of K [76.8, 102.4]kbps



Extensions Future Work

- Several Open questions
 - Better multi-session arbitration ?
 - Multiple Channels.
 - Fair policies for heterogenous environments.
- Explore applicability to OFDM systems
 - Perform power-control, sub-carrier allocation.

References

- [1] Mattar et. al. "TCP Over CDMA2000 Networks: A Cross-Layer Measurement Study", PAM 2007.
- [2] Ghaderi et. al "TCP-Aware Resource Allocation in CDMA Networks", MOBICOM 2006.